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AMERICAN WELDING SOCIETY

33 WEST THIRTY-NINTH STREET
NEW YORK, N. Y.

A. E. GIBSON, President

November 3, 1936

An open letter to—
The Members of the AMERICAN WELDING SOCIETY:

The recent annual convention in Cleveland established the high water mark in the history of the Society. The Metals Exposition, in number of exhibitors and general interest, far exceeded any previous ones. The registration for the technical sessions, the scope and character of papers presented, and the discussions following their presentation marked this year's convention as being the greatest one the Society has had, at least in the years of my association with it. These things are the outward evidence of interest and growth and development, encouraging mileposts in the history and progress of the AMERICAN WELDING SOCIETY. It is not, however, to these self evident signs of progress that I refer in saying that the convention last month set the high water mark in our development, but rather to the things which went on back of the curtain.

We are just emerging from a desperately long drawn out depression, a depression which has left strewn along our industrial highway a succession of broken down covered wagons and bleaching ox bones. For any technical society even to live through such a period is commendable. To make the progress which the AMERICAN WELDING SOCIETY has made in the past five years is truly remarkable. Sufficient credit cannot be given to your past administration, to your past committees who have unselfishly worked that there might be order and a definite procedure established in the art of welding, and to your headquarters staff which have unfalteringly carried on and refused to see the black clouds overhead.

Today, the situation has been reversed. Industry is decidedly on the up, welding is daily finding a new foothold in every conceivable kind of fabricated equipment. Thousands of new welding operators are being "made." Management and finance are welding minded. In short, the art of welding has outgrown its kindergarten, it has sprung into sturdy manhood, industrially speaking, almost overnight.

Now, what are we, the AMERICAN WELDING SOCIETY, going to do about that? We have before us an expanded field of operation. Our opportunity for service is staggering to the imagination. Will your Society accept the challenge which this changed condition presents? Will it accept the responsibility of coordinating, of directing, of expanding, of spreading the knowledge which our laboratories, our technical educational institutions and our industries are developing daily? Will it accept its real position as the one undisputed authority in the sphere of welding? The answer is, YES. There have been instituted by your Board of Directors certain definite policies, the accomplishment of which will build the AMERICAN WELDING SOCIETY into a Technical Society of unquestioned standing and prestige.

In a subsequent letter I will discuss these policies. Today I want to point out to you, your very definite part in this progress, your responsibility for contributing to this changed order which your Board and Officers have unanimously agreed upon.

No society is stronger than its local groups. We can only grow stronger as we strengthen our local sections. We can only accomplish this through you. The National Society will give our sections every help on technical programs and membership drives; however, we at headquarters can only help, it is you who are the ones on whom the real burden, the real responsibility rests. Just to indicate how simply results can be obtained, I want to tell you the story of the Cleveland Section over the past four or five months. Two men in the Cleveland district have brought into the Society 23 Sustaining Memberships (a Sustaining Member pays $100.00 a year). In three years the Cleveland Section has increased its Sustaining Members from one to twelve.

Just ten days before the annual meeting in Cleveland last month, our local Membership Committee of ten put on a quick drive in order that we might go before the opening Business Session with a concrete example of what could be done by a little concerted action. In ten days we brought in 54 new members. At our Membership Committee luncheon on October 30th, this Committee set themselves a new goal. We intend to enroll an additional 75 members by January 1st.

In accepting the high office which you have given me, I realized that heavy demands would be made on my time and effort. I accepted the honor with the determination that this year would produce a growth in members, a growth in service, a growth in accomplishments of which every member could be justly proud. We are going to do these things, not by and through your officers alone but by the combined efforts of all of us who are members in the Society. Remember this one thing, your Local Section is your job, your responsibility. It is you who must take the responsibility for our increase in memberships. In expecting your support, I know I shall not be disappointed.

Sincerely yours,

A. E. GIBSON, *President*

THE
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Characteristics of a Universal Welding Generator

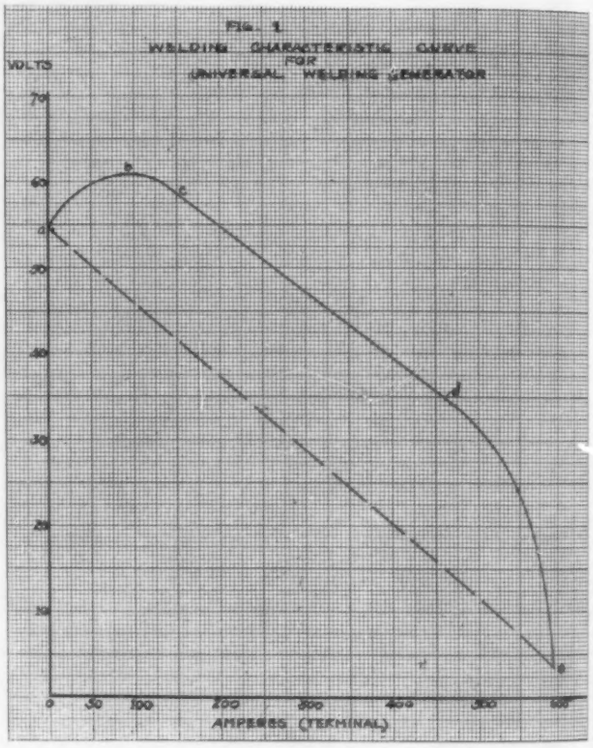
By NAIRNE F. WARD,[2] M.M.E.

THE increased demands upon arc welding equipment for deposition of welds in ferrous and non-ferrous metals of thicknesses varying from light-gage to heavy-plate is recognized as one of the major problems in arc welding art. That the solution of this problem is not an easy one may be seen when it is attempted to incorporate the necessary characteristics in a single welding generator. A small-capacity unit is unable to weld satisfactorily heavy gage. On the other hand, a welding generator of sufficient capacity for welding large plate generally cannot be used for welding light gage without the insertion of additional resistance, which is accompanied by necessary electrical losses.

For the purpose of increasing the range for welding of portable D.C. welding equipment, intensive research was undertaken to devise motor generator equipment capable of deposition of satisfactory welds in a single pass in light-gage and heavy-plate. The construction of this equipment was made possible by the experience and ingenuity of Mr. C. C. Roe,[1] whose cooperation in perfecting the design for the purpose intended is hereby gratefully acknowledged. How well this problem was solved with comparatively simple adjustments without recourse to external auxiliary devices may be seen in the following discussion:

While it is important to describe briefly the type of welder finally developed, the principal interest of this paper will be to outline its welding characteristics. Sufficient welding data are submitted to verify quantitatively the assumptions upon which the entire research was undertaken.

Intensive research has uncovered principles of D.C. power operation for the production of low- and high-capacity arcs with one unit which would be of interest to outline for the welding industry, although this is but one of the many important applications of this particular motor-generator. Before undertaking an extensive outline of the operating characteristics of this unit, it would be well to consider the characteristics of a welder which are necessary for all-purpose service. For operating conditions to satisfy welding requirements, the following are recognized as requirements for universal service; the open-circuit voltage be of such value that it will be safe for the operator; further, as a protection to the machine after arc is shorted, provision for unloading the generator would represent a very desirable feature. The heat generated at the arc should be a constant value; that is, the wattage output, or the product of the arc current and the arc voltage should remain constant in order to produce a uniform arc heat. Certain types of welding where high voltage and requisite current value must be developed—as, for example, certain types of non-ferrous welding, or heavily coated electrodes, or where moisture is present—a high ionization voltage represents a distinct advantage. Combined with these features, the machine, to have universal advantage, should develop an accretion of current sufficient in magnitude to supply heat of fusion at relatively high ionization voltage.



The regulation curve of this ideal welding generator is reproduced in Fig. 1. On this characteristic curve may be seen in *a-b* the voltage built-up which is required for ionization of the arc gap—of particular value in certain types of non-ferrous welding requiring simultaneous voltages and arc current to ignite readily the arc and maintain arc temperature.

It is commonly recognized that for steady weld deposition that a negative resistance characteristic of the arc requires a decreasing voltage to ionize the arc. For constant wattage or heat output, the current delivered to the arc by the generator increases. In order for the product of volts and amperes to remain constant, or in other words, develop constant input to the arc, the product of arc volts and amperes must bear a constant relationship as shown by curve *c-d*. The curve *b-c* is determined by magnetizing current in the magnetic circuits of the generator limiting the specific voltage increase.

For inputs below 3000 watts (20 volts at 150 amperes), considerable difficulty is experienced in maintaining the

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[2] Assistant Professor of Mechanical Engineering, University of California, Berkeley, California and Visiting Lecturer of Metallurgy, Boeing School of Aeronautics, United Airlines. Contribution to the Fundamental Research Committee.

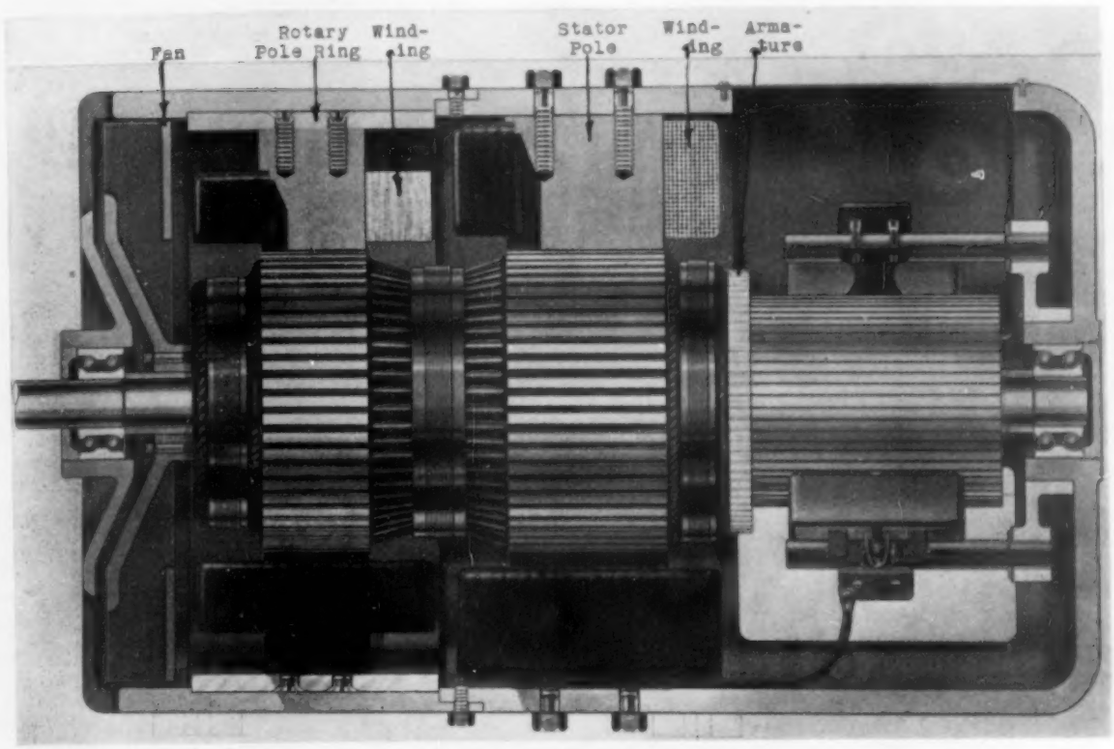


Fig. 2—Welding Generator Section

arc which is hot enough to give desirable penetration. Where the voltage decreases to short circuit magnitude, as is shown by oscillographic record (see Fig. 6), a residual value exists, due to imperfect separation of globule and rod, and imperfect assimilation of globule in the molten arc crater. This low arc voltage is insufficient to re-ignite the arc unless quick recovery is inherent in the type of generator winding. The relief of high, short circuit loads is obviously beneficial to the life of the generator brushes, windings, etc., if it involves no change in operating efficiency. The curve *d-e* (Fig. 1) indicates how regulation is such that the operator is prevented from holding too short an arc with its deficient penetration because the arc will generate less heat as the arc is progressively shortened below its satisfactory heat. In a way, the arc must be handled to induce a change in arc length until suitable heat is developed to fuse the deposited metal. Yet, a weld may be completed without an arc blow by burying the electrode in the molten weld to extinguish it.

The complexity of the generator for these characteristics is obvious when it is compared with the forerunner of D.C. arc welding—grid resistance (*d-e*) in Fig. 1, with its ideal arc regulation but limited welding range, and poor efficiency. However, it remains for the oscillographic record of the arc to demonstrate the transient changes occurring in the D.C. arc and indicate their relationship to more precise arc characteristics.

Description of Generator.—A generator to meet these conditions may be described as follows and differs in the following particulars from the conventional types, referring to Fig. 2.

1. The armature core consists of two parts; the armature proper with commutator rotating within the usual stator frame; and an extension under movable field poles excited by arc current and magnetically insulated by bushings of non-magnetic material (Fig. 2). The armature conductors are wound continuously in slots on the armature proper and its extended portion.

2. Provision is made for shifting the field poles circumferentially in axial relation to the stator pole pieces. In this generator the rotary pole ring and its windings may be shifted from approximate alignment with stator poles to an interpole position for field poles relative to the stator poles. In the neutral position, i.e., with pole ring pieces and stator poles in alignment, the generator output is a minimum. For the extreme adjustment, namely, with the rotary pole ring shifted to interpole location, the maximum output is generated.

3. Welding characteristics of the generator are largely controlled with the rotary pole ring which acts as a reactor. Yet, the pole ring can readily be wound for any characteristic desired.

Welding Range.—Experiments were conducted to determine the average terminal volt-ampere characteristics for this welding generator, the particular interest being in its suitability for open circuit arc-welding. The data for terminal volts and amperes variation were obtained by using grid resistance to absorb the generator output. Simultaneous values of terminal volts and amperes were obtained by varying the grid load for the range of rotary field pole settings. The resultant data appear in Figs. 3 and 4.

Discussion of Results.—The volt-ampere curve for the first pole ring setting shows a definite shunt generator characteristic in which the voltage drop below 14 volts is accompanied by the unloading of the generator with consequent protection to its windings. Throughout the volt-ampere range for this series field setting the output in watts remains practically constant. In other words, the heat available at the arc remains nearly constant from 14 to 40 volts, resulting in uniform weld deposition when the arc is maintained at constant length.

As the series pole ring is adjusted toward the interpole setting, the unloading tendency of the generator decreases, and approaches a series field characteristic. Two effects are noticeable, (*a*) an increase in watts or heat output with an increase of welding current demand

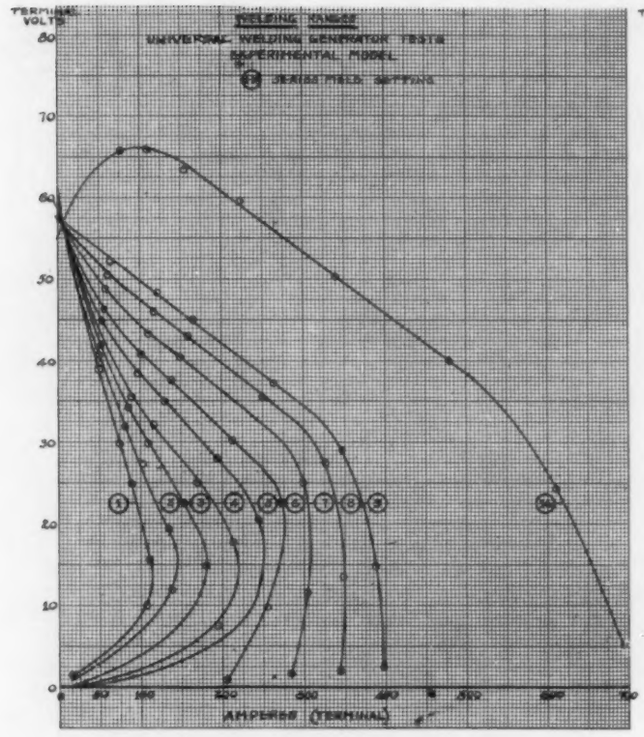


Fig. 3

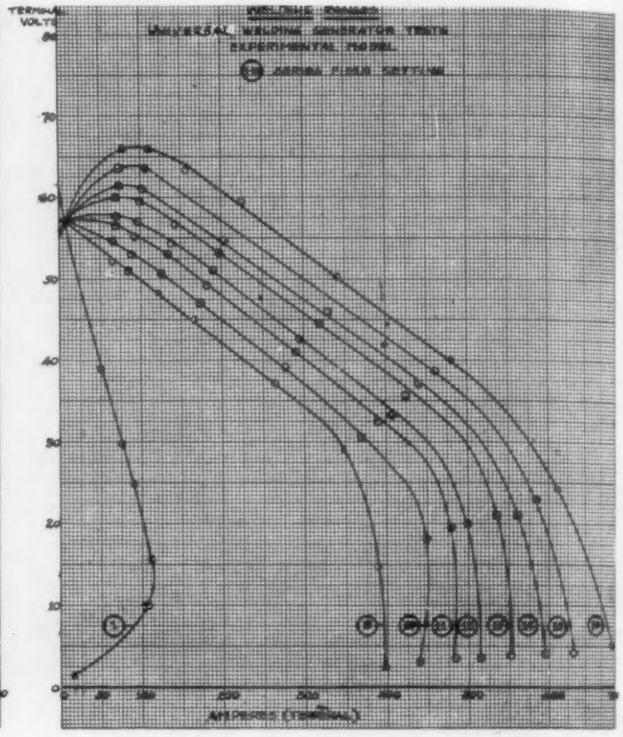


Fig. 4

which results in spattering of the red globule and loss of metal, (*b*) an increase in voltage for low ranges of welding current for settings above 12 on this generator. The latter characteristic has important application in welding with heavily-coated metallic electrodes where ionization is a factor, and for non-ferrous welding or welding of thin gage metals where heat control, which is markedly a function of arc current, is essential.

An extensive welding range at the usual welding voltages is indicated by these tests. At 40 volts, for example, the range in welding current is from 45 to 480 amperes, depending upon the setting of the field pole ring. For a welding voltage of 20, the current range varies from a minimum of 100 amperes to a maximum of 635 amperes.

A supplementary welding performance test, in the ranges given above, showed that for the intermittent service encountered in usual welding service, this generator does not show excessive overheating in field coils or commutator. Temperature rise tests demonstrated satisfactory limits for one-hour continuous operation.

Arc Volt-Ampere Characteristics.—In these tests on this welding generator, oscillograms were taken to determine, for the experimental model, the most important arc characteristics, these being transient arc phenomena such as arc stability, arc tenacity, and sticking or spattering tendencies of the welding arc.

Efficiency.—For the welding range of the experimental model of this generator, the efficiency is represented in Fig. 5. These represent increasing effectiveness of the motor drive or lessened power requirements for the work in hand. The efficiency values were computed by two methods: first, from ratio of motor-drive output to generator output; second, from the test operating the generator as a D.C. motor, from which the losses were determined, the efficiency was the ratio: $\frac{\text{Input} - \text{losses}}{\text{Input}}$.

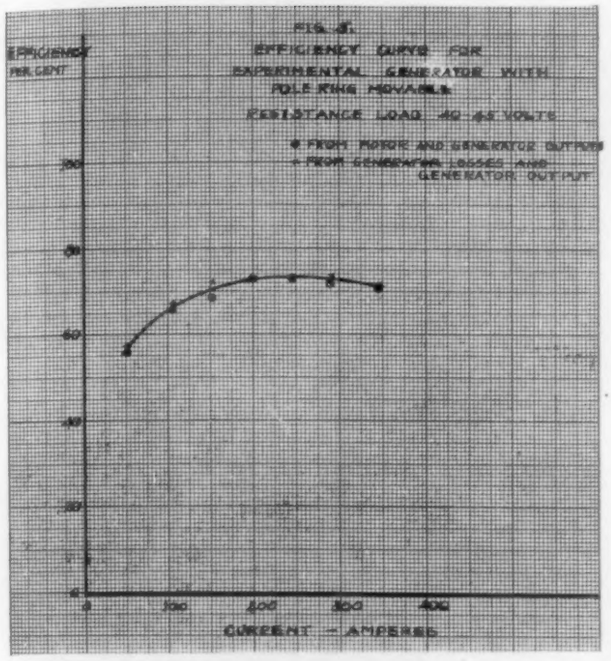
The agreement between the two methods of efficiency determination is close. However, the difference is attributable to the field losses within the rotary pole ring.

The increasing value of the pole ring field is reflected in the flat efficiency characteristic for the larger arc currents.

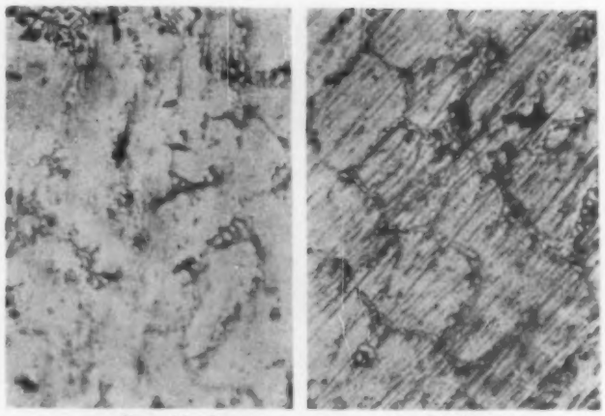
At the resistance load of two amperes and 40 volts, the following close agreement of efficiency is evident:

1.	Induction Motor Input	12,300 watts	
2.	Stator Loss	644 watts	
3.	Rotor Input		11,656
4.	Rotor Losses (Copper, windage and friction)	584	
5.	Motor Output = Generator Input		11,072
6.	Motor Efficiency (Item 5/Item 1)		90%
7.	Generator Output	8040	
8.	Generator Efficiency (Item 7/Item 5)		72.6%
9.	Generator Loss (Total Including Losses—I^2R, Rotation Losses, Shunt Field, Series Field, Reaction	3108	
10.	Generator Input = Output Plus Losses (Item 7 + Item 9)		11,148
11.	Generator Efficiency (Item 7/Item 10)		72.2%

Short to Open Circuit Test.—The oscillogram in Fig. 6 measures the inductive kick of the welding unit when the welding circuit of the loaded generator is opened. This condition is a measure of the arc tenacity for unsteady welding operations. These conditions prevail while using long arcs or during manual welding where the hand is unsteady. Referring to Fig. 6, the generator builds up the arc voltage to 74 volts with the extinction of the arc because it is in excess of the voltage which is necessary to maintain the normal welding arc. These conditions show that the arc can be maintained without



difficulty since the normal welding current is maintained during the increase of arc voltage. The recovery to within 5% of the open circuit voltage requires 0.25 of a second. But the voltage at the time of total arc extinction is 22 volts which is adequate for normal open circuit welding voltage.



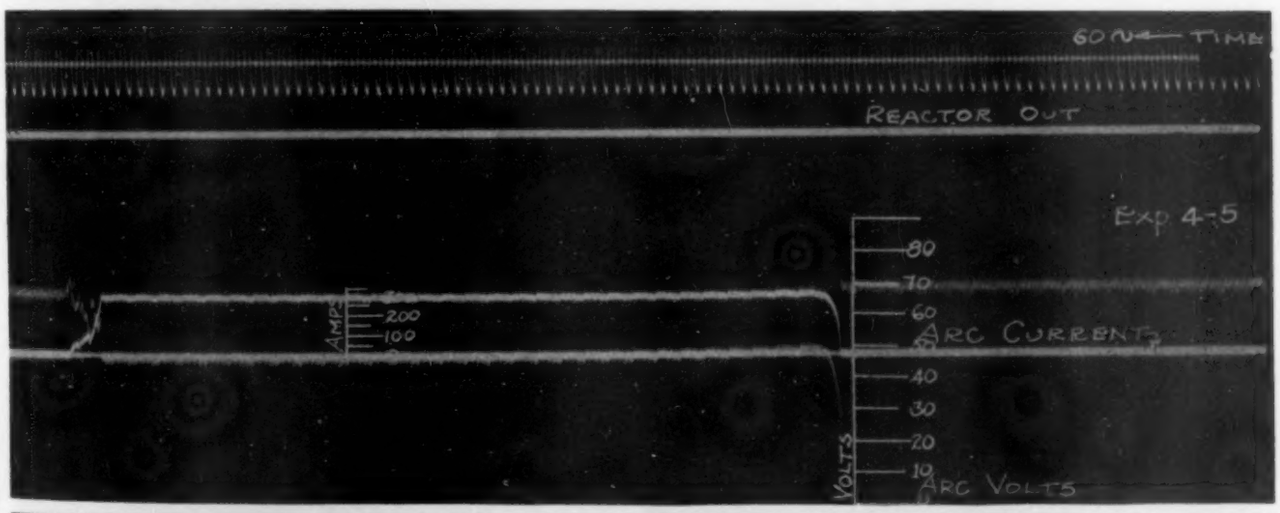
a. Parent Metal b. Weld Metal

Fig. 9—Original Metal—2 Inch Thickness 112 Aluminum Alloy Casting 130 X. 0.5 HF Etch

The oscillogram in general shows the increasing effectiveness of the rotary field pole as it approaches the interpole position.

Short Circuit Test.—The results of this test appear in Fig. 6, for 300 amperes resistance load.

The recovery of current to normal welding value of 300 amperes, Fig. 6, is accompanied by only slight over-



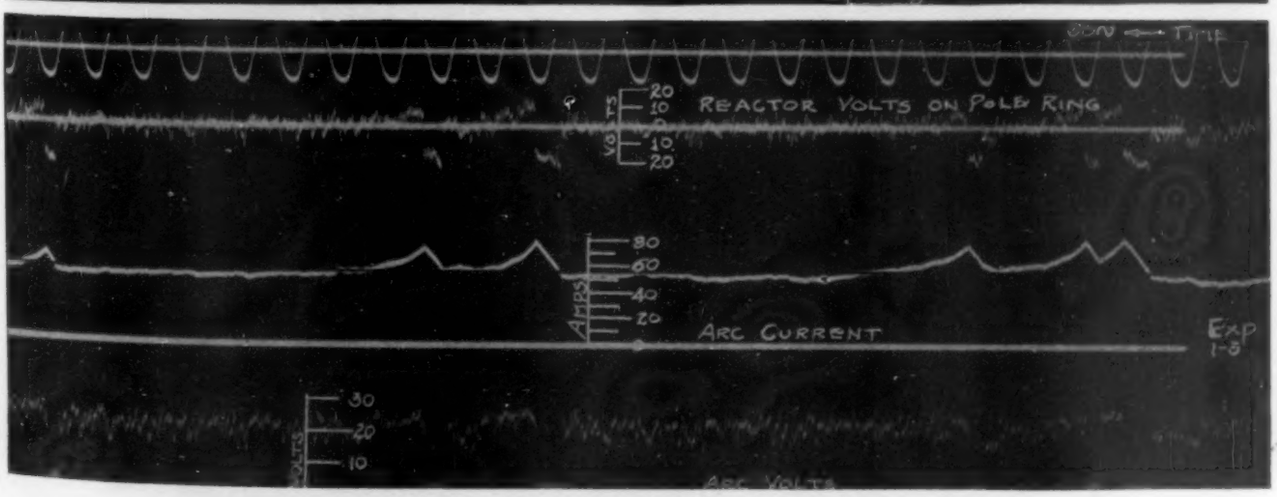


Fig. 6 (Top)—Short to Open Circuit Tests for Universal Welding Generator
Fig. 7 (Bottom)—Arc Welding Characteristics of Universal Arc Welding Generator

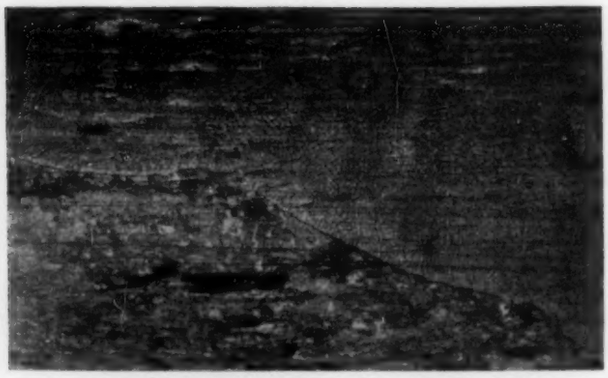
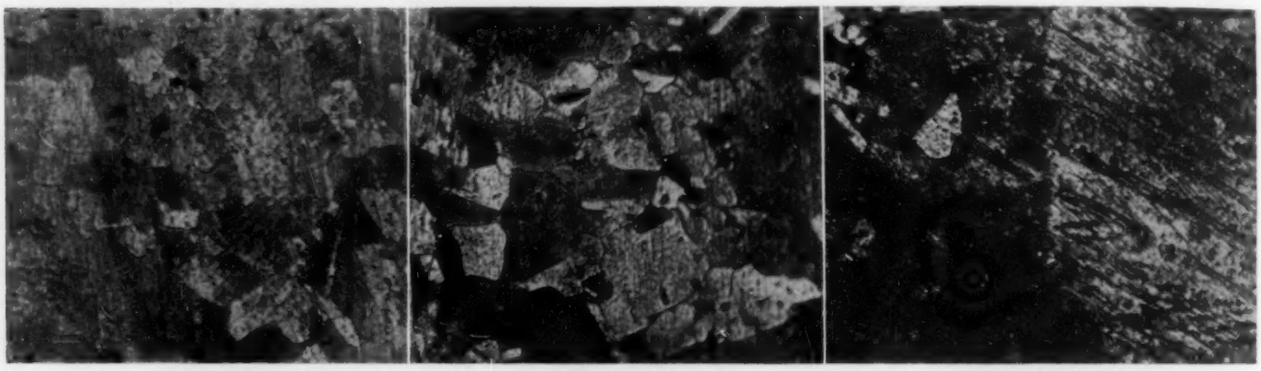


Fig. 9—Copper Metal and Phosphor Bronze Electrode 35 X

ride (i.e., percentage in excess of normal current). This initial short circuit current does not sufficiently saturate the iron circuit to produce any noticeable under-ride which often increases sticking tendency of the electrode. Spattering of the weld metal in the arc is a minimum since the arc current is not sufficiently in excess of its normal value for extended periods as Fig. 7 shows.

With higher current outputs of the generator the series field position practically eliminates the current surges upon shorting the arc. (See Figs. 6 and 7.) However, the maximum current is developed without serious consequences. Inclusion of common reactor in the welding circuit is not essential for steady arc conditions. Another method of showing this effect is seen with arc volt meter (undamped fluctuation) which varies between 2 and 4 volts during welding.



a. Original Copper b. Transition Zone c. Weld with Phosphor Bronze Rod

Fig. 10—Arc Welded Copper 130 X

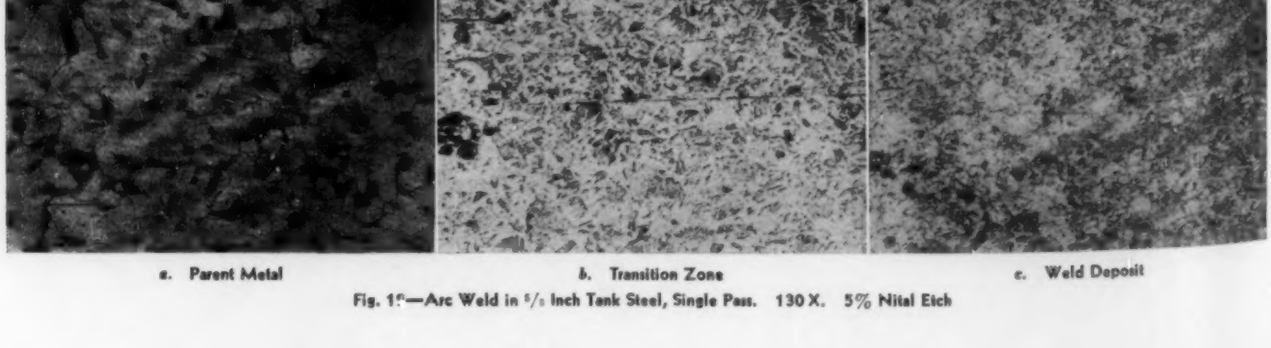
a. Parent Metal b. Weld Metal

Fig. 11—Arc Weld in $^{1}/_{16}$ Inch Soft Iron Sheet 130 X Coated Electrode Used. 5% Nital Etch

Welding Characteristics.—The versatility of this generator may be grasped from a series of successful applications with the aid of suitable metallic electrodes. Aluminum deposited in 112 aluminum castings, while at sweating preheat, shows excellent penetration and fusion which appears in Fig. 8. The weld structure has inappreciable grain alteration. This weld was produced with the generator producing 200 amperes at 35 volts.

Various gages of copper bus bar represent another metal successfully welded with bare phosphor bronze rod. Photomicrograph of light-gage copper ($^{8}/_{64}$-inch) appears in Fig. 9 and similar fusion and penetration in $^{1}/_{8}$-inch copper bus bar appears in Fig. 10 *a. b. c.* Welds of $^{1}/_{8}$-inch flat specimen had a tensile of 31,280 lb. per sq. in. and ductility of 43%, while tensile of original copper was 31,800 lb. per sq. in. and ductility 56% in 4-inch.

The range of steel welded is indicated for light-gage low carbon steel of $^{1}/_{16}$-inch thickness in Fig. 11 with a



a. Parent Metal b. Transition Zone c. Weld Deposit

Fig. 12—Arc Weld in $^{5}/_{8}$ Inch Tank Steel, Single Pass. 130 X. 5% Nital Etch

bead reinforcement less than 0.8 the thickness of the sheet. The fine-grained weld structure is evidence of intense concentration of high temperature and rapid cooling; similar tests on light-gage sheet show successful fusion with only slight reinforcement.

Five-inch steel plate, when welded in a single pass by suitable pole ring setting, appears in Fig. 12 *a*, *b*, *c*. The fine grain of steel weld is characteristic of this welding generator.

Summary.—A brief outline of this generator shows the universal application to the production of the welding arc for a wide range of metals. The presence of a fine-grained weld which is regulated easily to the work in hand may be seen during the operation of this equipment. A minimum of adjustment without external auxiliary devices is recognized as less wasteful and more productive of an arc capacity equally adapted to light-gage and heavy-plate welds, with an increase of generator efficiency and probable increase in service life of the equipment.

Importance of Design Control for Welded Piping Systems*

By T. W. GREENE†

AS IS WELL known, the utility of welding and the success obtained with it over a period of years has led to its general acceptance as an almost necessary means of joining pipe. The advantages of welding are so marked and so well recognized that they need not be repeated. Its general use for extremely high temperatures and pressures and combination of both where other joints have given trouble is a testimony to the merits of welding. In fact, because of its advantages, welding has contributed to, if not been responsible for, the use of higher and higher pressures to effect a more efficient utilization of materials and economy in installation.

It is a highly desirable development to take advantage of the adaptability of welding to use thinner pipe, to increase the operating stresses, and to construct compact economical installations. With the use of the butt joint, ideal from a stress distribution standpoint, and with welds developing the full strength of pipe or base material, welding permits economies in the use of thinner material not possible with other types of pipe joining, and it is only a question of time until installations will generally be designed primarily on the basis of welded construction rather than on the basis of adapting welding to materials manufactured to suit older methods of pipe joining. To gain the full benefit of welding this development is inevitable, but it is important to recognize that sound engineering consideration must be given to various piping details whether welded or fabricated by other means. In fact, it is more important if operating stresses are to be justifiably increased for the danger necessarily increases. Moreover welding, because of its seal-tightness, even up to the breaking point or ultimate strength, often hides defects and inadequacies in design that might otherwise be manifested with a different type of construction.

Code for Pressure Piping

The American Standards Association published in 1935 a Code for Pressure Piping which undoubtedly will stimulate the development and progress of welding in this field as much as the A. S. M. E. Unfired Pressure Vessel Code has influenced welding in its field. In this code welding is not only recognized without limitations or restrictions, but assumes an important part throughout the Code as it rightly should as a meritorious method of fabrication. The Code for Pressure Piping acknowledges the advantages of welding, or rather a relative disadvantage of threaded joints in permitting thinner pipe to be used for welded construction than for threading. This varies for different services covered by the various sections of the Code, but as an example, the Power Piping Section stipulates that for inspection purposes the minimum thickness of pipe wall shall be determined by the following formula:

$$t_m = \frac{PD}{2S} + C$$

where t_m = minimum pipe wall thickness in inches
P = maximum internal service pressure in lb. per sq. in.
D = actual outside diameter of pipe, in inches
S = allowable stress in material, in lb. per sq. in. and
C = allowance for threading, mechanical strength and/or corrosion, in inches.

The value of C used in the formula shall not be less than that given for the respective material in the following list:

Type of Pipe	Value of C in Inches
Threaded steel, wrought iron or non-ferrous pipe	Depth of Thread
Plain end steel, wrought iron or non-ferrous pipe or tube for sizes above 1 in.	0.065

As the value of C to be used in the above formula for threaded pipe is 0.1 in. for pipe sizes $2^1/_2$ in. and larger, the pipe thickness must be increased this amount over that required by the common pressure formula as against 0.065 in. for welding. Welding thus permits a saving of 17 to 11 per cent for standard pipe thicknesses $2^1/_2$ in. to 10 in., respectively. This is some recognition of the

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* Paper presented at the Annual Meeting, AMERICAN WELDING SOCIETY, week of October 19, 1936, in Cleveland.
† Process Development Department, The Linde Air Products Company.

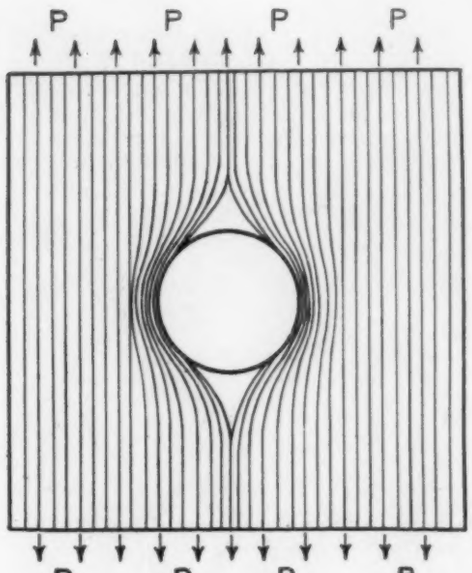


Fig. 1—Graphic Illustration of Stress Concentration Around Openings

advantages of welding although not to the extent justified. However, there are other restrictions stipulated in the Code limiting threaded joints still further when used for steam or other high pressure services.

The value of design stress S in the above formula varies in different sections and services covered by the Code, also for different materials. The stress values S in the Power Section for temperatures as high as 750° F. are 9000, 11,500 and 14,000 for seamless pipe grades A, B and C, respectively, lower values being stipulated for lap-welded and other materials. Actually, however, the normal stresses are usually rather low because of the effect of the constant C, the necessity of allowing 12½ per cent manufacturer's tolerance for possible thinning, and the requirement of using the outside diameter of the pipe in the pressure formula which errs on the side of safety.

The nominal stresses in pipe employed for the usual pressures encountered in every day practice are generally quite conservative. Table 1 shows these stresses for

Table 1—Stress in Pipe for Different Pressures

Pipe Size, In.	Outside Diameter, In.	Wall Thickness, In.	Hoop Stresses (lb. per sq. in.) under Pressures of 250 lb	500 lb.	800 lb.	1800 lb.
6	6.625	0.280	2800	5,600	9,000	20,000
10	10.75	0.307	4400	8,800	14,000	31,500
20	20.00	0.3125	8000	16,000	25,600	....

different pressures in a few typical pipe sizes. It is only where the diameter is large and the pressure high at the same time that really high stresses are developed. However, some industries, particularly the natural gas industry, of necessity use rather high stresses. The Pressure Piping Code in the Gas and Air Section permits extremely high stresses for installations in compressor stations, cross-country transportations lines and systems outside of boundaries of cities and villages. The maximum allowable working pressure for such systems, according to the Code may be determined by the following formula:

$$P = \frac{2Yt}{FD}$$

where Y = yield point or yield strength for respective material and method of manufacture as determined by the Code
t = nominal or specified pipe wall thickness in inches
F = a factor not less than 1.4
D = specified outside diameter of pipe in inches

This formula indicates that operating stresses may be as high as 71 per cent of the yield point. For materials having a yield point of 35,000 lb. per sq. in., the design operating stress may be as high as 25,000. Installations of extensive magnitude are actually in successful operation at stresses even higher.

Pressure Stresses Around Nozzles

Experience with overland lines and other installations has demonstrated that high pressure stresses, probably from 15,000 to 25,000 lb. per sq. in., are both safe and justified with welded construction for straight line joints with the understanding, of course, that the design has adequately provided for all external loadings and strains that may cause superimposition of stress. But every installation requires special fittings and fabricated specials. Moreover in the fabrication of specials the normal expected stresses may be increased many times due to the imposition of concentration of stresses or to bending, and this must be designed for if the construction is to be safe.

Practically all fabrication involves the welding of nozzles. It is important to examine the effect of removing a part of the pipe for a nozzle. The effect of an opening on the normal stress distribution can probably best be represented by a graphical illustration of stress lines as shown in Fig. 1. In Fig. 1 the plate is assumed under a uniform load P acting in one direction. The stresses set-up by the force may be represented as flow

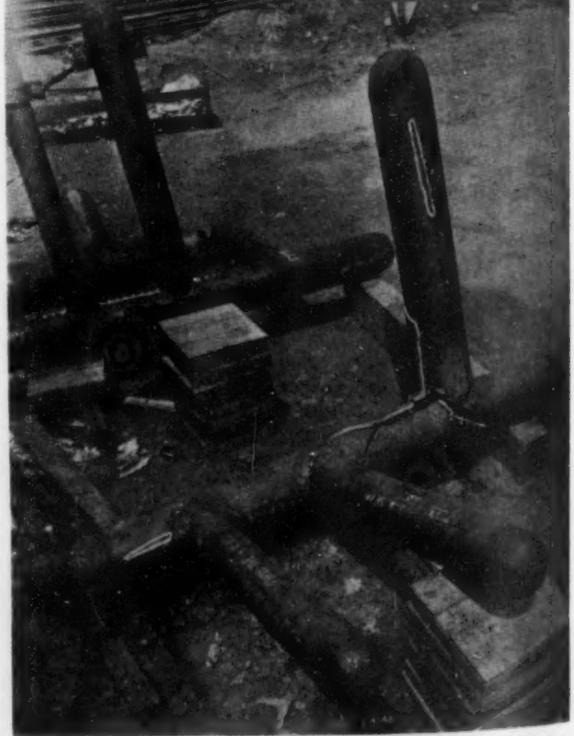


Fig. 2—Failure of Header B. Header Size 10 In. x 0.75 In. Wall, Seamless. Nozzle Size 10 In. x 0.75 In. Wall, Seamless. 8 In. x 0.625 In. Wall, Lap-Welded. 6 In. x 0.50 In. Wall, Lap-Welded
Failure Occurred at 6500 Lb. per Sq. In. Pressure, with the Fiber Stress in the Header 46,500 Lb. per Sq. In.

lines as shown in the Figure. These are uniformly distributed if the load is uniform and if there is no opening, and the concentration of the lines may be considered as an index of the stress intensity.

If a hole is cut in the plate, the flow or stress lines must transfer around the opening. Unfortunately they will not distribute throughout the remaining metal but will take the shortest path, concentrating at the edge of the opening. It can be shown theoretically that for a plate stress in one dimension the stress intensity at the edge of the opening is three times that in the plate at a distance from the opening. Where the load stress is uniform in all directions, as in the head of a pressure vessel, the stress at the edge of the opening is theoretically twice the normal stress.

In pipe, which is subjected to a hoop stress and also to a longitudinal stress of half the value of the hoop stress, the theoretical concentration factor is somewhere between two and three. The attachment of the branch pipe or nozzle by welding, of course, reinforces the opening to some extent, but not enough to equal the pipe itself. Some tests have been made of nozzle connections both in pressure vessels and piping, and this subject is now under consideration by a special committee of the American Standards Association, who are planning to conduct extensive tests, looking toward setting up recommended practices to be incorporated in the A. S. A. Code for Pressure Piping.

In studying this subject, it is of particular interest to review a few tests of headers made some time ago jointly by the Power Piping Society and The Linde Air Products Company. These tests were made on steel pipe with thicknesses required in power piping practices. The results are interesting and illuminating. Table 2 gives the different headers investigated. The headers were constructed with one to three nozzles welded into each header pipe. The wall thicknesses of the pipe were $^3/_8$, $^1/_2$ and $^3/_4$ in. in compliance with Power Piping Society specification for operating pressures of 250, 400 and 900 lb. per sq. in. The welding was done by competent oxyacetylene operators with high strength welding rod and in every detail represented excellent construction.

Fig. 3—Failure in Header E. Header Size 12 In. x 0.5 In. Wall, Lap-Welded. Nozzle Size 12 In. x 0.5 In. Wall, Lap-Welded Header Failed at 2755 Lb. per Sq. In.; Stress 35,100 Lb. per Sq. In.

The headers were tested hydrostatically to destruction, with elaborate strain gage measurements being taken around the nozzles at known critical points as well as in the pipe away from nozzle connections, in order to determine the stress concentrations around the openings as compared with normal stresses in the pipe away from the openings. The results of these tests are shown in Tables 2 and 3.

It will be seen that these headers failed under hydrostatic pressures producing normal hoop stresses in the pipe of from 25,000 to 45,000 lb. per sq. in. or, on an average, less than 75 per cent of the expected strength

Table 2—Test of Power Piping Headers

	Header		Nozzle		Allowable*	Hydrostatic Test Results		
Header Test No.	Pipe Size, In.	Wall Thickness, In.	Pipe Size, In.	Wall Thickness, In.	Working Pressure in Header Pipe, Lb. per Sq. In.	Bursting Pressure, Lb. per Sq. In.	**Stress in Header at Failure, Lb. per Sq. In.	Failure
A	10	0.365	10	0.365	250	1705	25,100	8-in. nozzle weld cracked at 90-deg. intersection
			8	0.322				
			6	0.280				
B	10	0.750	10	0.750	900	6500	46,500	Header rupture through 90-deg. intersection with 10-in. nozzle
			8	0.625				
			6	0.50				
E	12	0.5	12	0.5	400	2755	35,100	Header rupture through 90-deg. intersection with 12-in. branch

* Power Piping Society Specification

** Stress $= \frac{PD}{2t}$, Barlow's formula ($D = O.D.$)

Table 3—Comparison of Relative Stresses

(Stresses around branch connection at 90-deg. intersection point to normal stresses in header removed from opening.)

	Header		Allowable*			Ratio $= \frac{\text{Stress around nozzle opening}^{**}}{\text{Normal stress in header pipe}}$			
Header No.	Pipe Size, In.	Wall Thickness, In.	Working Pressure, Lb. per Sq. In.	Working Stress, Lb. per Sq. In.	Factor of Safety Bursting Strength	For 12-In. Branch	For 10-In. Branch	For 8-In. Branch	For 6-In. Branch
A	10	0.365	250	3700	6.8	..	2.28	2.00	2.00
B	10	0.750	900	6400	7.2	..	1.42	1.41	1.19
E	12	0.500	400	5100	6.9	1.67	..	..	..

* Power Piping Society Specification

** Stress determined from strain gage reading to determine pressure that caused yielding of the material.

Fig. 4—Photograph—Header A, Showing Location of the Groups of Gage Lines for Header Tests. The Boxlike Group Are for Two Transverse and Two Longitudinal Gage Lines for Measuring the Deformation of the Header Pipe Removed from Any Opening Influence. Turnbuckle for Imposing Bending Force on Branch Connections Is Shown

of the pipe based on a minimum strength of 45,000 to 55,000 lb. per sq. in. specified for the low carbon pipe material. Of particular interest is the method of failure. Failure in every case occurred by the longitudinal splitting of the pipe at the top of the header where the nozzle connection makes a right angle intersection with the header pipe. Figures 2 and 3 show the failure of these headers. This is the critical point in nozzle or branch attachments as high concentrated stress occurs at this point. The reason for this is evident from the explanation previously given of the stress transfer around and opening. The hoop stresses set-up in the header pipe resisting the internal pressure must transfer around the nozzle opening. They do not transfer evenly either in the header or branch pipe but concentrate at the critical point where the branch makes a right angle intersection with the header pipe.

In Table 3 are presented the stress-raising factor determined for the various size nozzles in these header tests. These were obtained by strain gage measurements at which the yield point of the material was exceeded at the critical point around the nozzle as compared to the yielding of the header pipe at a distance from any opening. It will be seen from the table that the stresses at the nozzles were from 1.2 to more than 2 times the normal hoop tension in the pipe.

It should be emphasized that in spite of the fact that high stresses are concentrated around the branch openings and that the headers failed at approximately 75 per cent of the strength that would be developed with the pipe without openings, the headers are amply safe for the design working pressure. An average factor of safety of 7 was developed as shown in Table 3. This is due to the conservative design required in power piping practice. The normal stress in piping for usual pressures rarely exceed 3000 to 6000 lb. per sq. in. Thus, if a stress concentration of twice this amount occurs as shown in these tests, the maximum stress is still relatively low, and the factor of safety is ample.

It is of interest to examine the effect of such stress concentration with the high pressure stresses given in Table 1. If high stress of 15,000 to 25,000 lb. per sq. in. which is safe for a straight run of pipe, is used in the design of headers, branch connections, drips and other fabrication details, it may be possible to have stresses as high as 30,000 to 50,000 lb. per sq. in. at critical points in the header. It can readily be seen that such practice is not safe. In fact, instances are known where headers designed on such high stresses have failed through the critical points under tests of only $1^1/_2$ times the expected working pressure, much to the surprise of both the designer and fabricator.

Superimposition of Bending Stresses

In all piping systems expansion and contraction are factors of more or less importance, depending upon the temperature change. Means must be provided for movement either by expansion joints, bends or in the flexibility of the system itself; otherwise the forces will impose stress. This feature is carefully considered for steam and low temperature refrigeration lines and, fortunately, in other installations, this is not generally a serious factor because of the surprisingly inherent flexibility of piping systems. However, it may be of interest to determine the effect of such superimposition of stress resulting from movement.

Header "A" of the previously mentioned tests was subjected to a special test in which the 6-in. and 8-in. branches were deflected by means of a turnbuckle. Figure 4 shows this turnbuckle in place. In this test, the 6-in. branch was deflected $^1/_2$ in. at a point 54 in. from the header, and the 8-in. pipe, about half this amount. The purpose of this test was to simulate the force that might be thrown on a nozzle connection through the expansion-contraction in the branch piping. The test was somewhat severe and represented a condition rather unusual for actual installations, where two branches would rarely be deflected toward each other when placed so close together. Header "A" was tested to destruction under the imposition of the turnbuckle force.

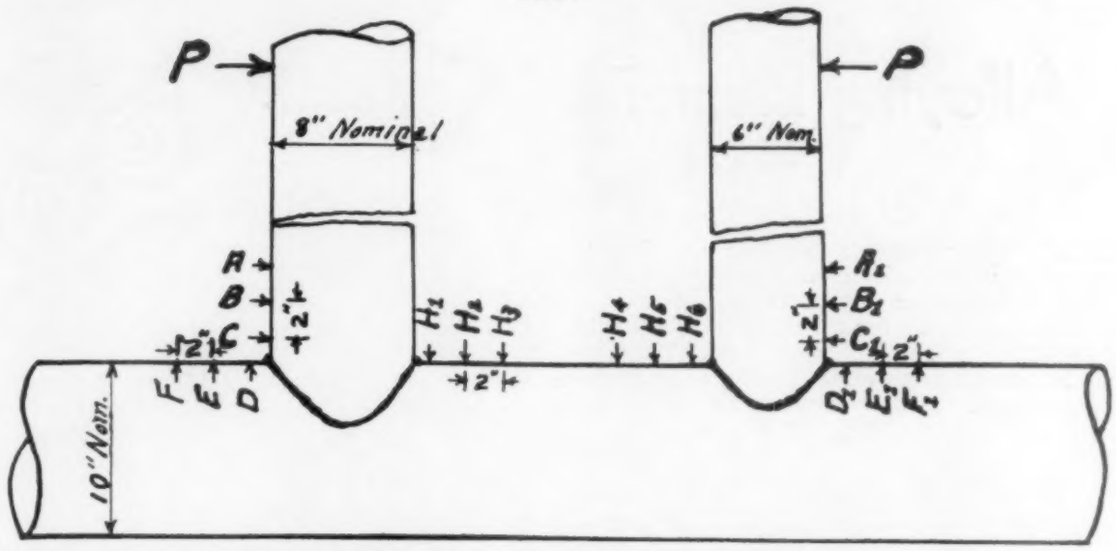
Although this deflection test in header "A" was somewhat impractical, it is interesting to determine the nature of the stresses set-up and the action of the header under such external force. To deflect the 6-in. pipe $^1/_2$ in. means that a bending stress (based upon the common formulas of a cantilever beam, rigidly held) of 51,000 lb. per sq. in., would be set-up, providing the elastic limit was not passed. In other words, it would be expected that the branches would be permanently bent. As a matter of fact, the deflection of $^1/_2$ in. did not permanently distort the header nor were stresses anywhere near this magnitude imposed, the reason being that in header construction the branches are not rigid cantilever beams, for the header pipe bends and deforms as the branches are deflected. The metal between the two branches was thrown into compression as shown by the strain gage measurements and had readings been taken on the opposite side, they would have shown, no doubt, tension.

Table 4 gives stress distribution around the 6-in. and 8-in. branches and in the header pipe at the points measured. The Table also indicates the increase of stress at 1000 lb. per sq. in. internal pressure imposed by the deflection of the two branches. It will be seen that stresses imposed by deflection were superimposed on those measured under pressure alone.

Stress-Relieving of Piping

Stress-relieving of welded piping has always been a moot question. In spite of the study and experimentation devoted to the subject of residual stress, little definite knowledge yet exists, and one must necessarily rely upon practical application for guidance. One fact should be borne in mind; namely, that residual stresses are not necessarily superimposed on those caused by pressure or bending which is unlike the condition of stress superimposition under different external forces. Where the individual fibers of the metal are subjected

Table 4



Measured Superimposed Bending Stress from Deflection of 6-In. and 8-In. Branches, Header "A"

Position	*A*	*B*	*C*	*D*	*E*	*F*
			Stress in Girth Direction			
Pressure 0*	800	2,000	11,400	7,000	7,100	6,400
Pressure 1000*	6,600	− 1,000	Y. P.	18,400	5,600	1,800
			Stress in Longitudinal Direction			
Pressure 0	9,500	10,000	13,000	11,000	8,700	6,400
Pressure 1000	2,500	4,100	14,500	3,400	1,700	2,000
Position	A_1	B_1	C_1	D_1	E_1	F_1
			Stress in Girth Direction			
Pressure 0	− 4,000	500	27,800	22,000	7,000	11,900
Pressure 1000	− 2,000	− 2,000	Y. P.	Y. P.	10,000	8,600
			Stress in Longitudinal Direction			
Pressure 0	16,800	19,700	29,400	17,100	10,200	9,600
Pressure 1000	10,200	8,100	15,400	18,200	5,100	2,500
Position	H_1	H_2	H_3	H_4	H_5	H_6
			Stress in Girth Direction			
Pressure 0	−16,600	− 7,600	− 6,700	− 8,400	− 8,800	−19,800
Pressure 1000	− 7,200	− 8,600	− 7,900	− 7,800	− 9,500	−17,200
			Stress in Longitudinal Direction			
Pressure 0	−19,300	−14,200	−12,200	−13,000	−14,300	−18,000
Pressure 1000	−14,200	−13,100	− 9,300	−12,800	−14,500	−15,400

* Header A was previously tested to 1000 lb./sq. in. pressure to investigate yielding around nozzle. Pressure was then released and nozzles deflected. The stresses reported at 0 pressure are those resulting from deflection of nozzles. Stresses reported at 1000 lb. pressure are additional stresses as compared to stresses previously measured under 1000 lb. pressure without deflection of nozzles.

to stress approaching the elastic limit of the material, there occurs unavoidably a readjustment and ironing out of stresses. In considering this problem, one must face the fact that millions of welded pipe joints and thousands of pressure vessels unstress-relieved have given satisfactory service.

Fortunately piping offers one of the most favorable shapes from the standpoint of residual stresses. The A. S. A. Piping Code requires stress-relieving only when the pipe wall thickness is $^3/_4$ in. or greater. This division is of course somewhat arbitrary but it is based upon consideration of two factors; (1) rigidity, which naturally becomes important when the thickness reaches a dimension as great as $^3/_4$ in., and (2) the appreciation of the pressure hazard, as such thick walls are generally used with high pressures. The division also follows somewhat that set-up and successfully applied in the pressure vessel field. Experience and practice have proved that the provisions of the Piping Code are safe, and it is believed that they can be employed as a practical guide.

Weld Quality

No mention has been made of weld quality. Weld quality, of course, is most essential. Data have been presented before the AMERICAN WELDING SOCIETY on tension tests of full pipe joints which showed that weld quality is more important than stress-relieving of pipe welds.* Of particular harm is the lack of penetration or fusion at the bottom of the butt joint, for the effect is that of a notch. In this case the concentration of stress is serious because it superimposes and accentuates the normal stress on the joint.

In appreciation of this factor liners have been advocated at times to back up the weld, and have been applied to some extent for electric-welded joints. However, they resist the flow in the line and by exercising a little care in spacing and welding the first bead, a satisfactory butt-welded joint can be obtained. For gas welding, liners are not advocated since by proper control of the flame and welding rod, full penetration can be assured to the bottom of the vee.

With improvement and advancement in welding, welds of consistently high quality are assured as the most satisfactory means for joining pipe, but such assurance, as pointed out in this paper, has not eliminated the necessity of applying sound engineering consideration to important details of welded piping.

* "Weld Ductility Requirements for Welded Pressure Piping" by T. W. Greene, Journal of the AMERICAN WELDING SOCIETY, April 1932.

Alloying Elements in Welding Rods*

By A. B. KINZEL†

WHILE alloying elements have been used in both ferrous and non-ferrous metallurgy for many years, it is significant that the development of their larger commercial use has been coincident with the development of the fusion welding processes. The common factor has been a better understanding of high temperature metallurgy. In the very early days of fusion welding, material used as welding rod or filler metal was identical with that to be joined. It was not long, however, before it was realized that this simple rule did not suffice, that certain additional phenomena took place in the welding operation, and that these phenomena could be directly influenced by the presence of relatively small amounts of impurities or of alloying elements.

Early Use of Norway Iron

The first step in the direction of special welding rod in the ferrous field was the use of commercially pure iron. The filler metal which best meets this requirement and which was available even in the early days of welding is "Swedish" or "Norway" iron containing no more than 0.06 per cent carbon, with manganese below 0.20 per cent, phosphorus below 0.020 per cent and sulphur below 0.030 per cent, all other elements being absent or present only as traces. On deposition, some of the carbon and manganese is lost by oxidation, the carbon being reduced to about 0.03 per cent and the manganese to about 0.07 per cent. The phosphorus and sulphur remain about the same. This has long constituted the iron base on which other welding rods with special characteristics have been designed, and has given such excellent ductility in the deposited metal that it is still utilized to a very large extent. Great care must be exercised in welding to prevent too much oxidation of the iron. The sparking which takes place during the operation damages the scarf, and the soundness of the deposited metal depends in a large measure on the ability of the welding operator to puddle it in such a way as to minimize the presence of slag inclusions in the weld proper.

Improvements Through Addition of Deoxidizers

The disadvantages of this iron rod were sufficient to stimulate thought and experimentation. The major improvement of the last decade resulted in the steel welding rod and consisted in the addition of carbon and deoxidizing materials whose oxidation products were self-fluxing. This story has been told often, having been given in detail in the writer's paper before the 11th International Congress in 1934, so that at this point it is necessary only to summarize with the statement that silicon is the prime deoxidizer for use in steel welding rods, and manganese combined with the silicon in proper proportion results in self-fluxing inclusions and slag coverings of the desired viscosity. The presence of these deoxidizers also allows an increase in the carbon content to a range from 0.15 to 0.20 per cent, and permits greater leeway with respect to phosphorus and sulphur. The melting range of the rod is reduced about 50° F., and the flowing characteristics greatly improved.

The addition of about 0.5 per cent silicon and 1.0 per cent manganese may well be considered as the major alloy improvement in steel welding rods. Indeed, these additions in modified quantities but following the same principle will be found in most modern complex alloy steel welding rods and may be considered as fundamental. The silico-manganese rods give weld metal with the full strength of the steel plate—up to 70,000 lb. per sq. in. and with ductility of more than 15 per cent elongation on free-bend test. Attempts at other alloy combinations to achieve the same results in the 70,000 lb. per sq. in. tensile range welding rod have been made. The use of nickel instead of manganese and the use of vanadium as an additional deoxidizer have been tried but zirconium is a more promising element in this respect. It combines readily with oxygen, nitrogen and sulphur, and the reaction products are readily fluxed. In this tensile range, the silico-manganese combination is still in greatest favor, being as yet unsurpassed in welding quality and representing the most economical of the alloying possibilities.

Carbide-Forming Alloys Give Higher Strength

When higher strength in the deposited metal is desired, the addition of strong carbide formers to the silico-manganese base has given successful results. The use of chromium or molybdenum in quantities approximating 0.5 per cent has resulted in a welding rod having a tensile strength of 100,000 lb. per sq. in., with reasonable ductility. In general, it has been necessary to maintain the silicon at its base level in order to have sufficient protection against oxidation of the carbide-forming element, and in order to maintain the proper slag viscosity it has been necessary to further increase the manganese content.

To obtain hardness for wear resistance, surface deposition of hard-facing rods is used. These rods are again a matter of alloy addition. The well known 1.5 per cent chromium rod for building-up rail ends and the well known 1.0 per cent chromium and 0.25 per cent molybdenum rod for general-purpose hard-facing are illustrative. The use of the oxy-acetylene flame with these rods allows controlled hardness over wide limits by means of controlled carbon pick-up from an excess acetylene flame. It is interesting to note that even when very large amounts of alloying additions are involved such, for example, as the stainless steel type or the 8 per cent chromium and 4 per cent manganese type of hard-facing material, the basic principles remain the same—always enough silicon to protect the metal proper, together with enough manganese to give suitable slag viscosity, and with chromium carbide as the essential strengthener and hardener.

Columbium Additions Improve Stainless Steel Rods

One of the most spectacular of recent achievements in alloy steel welding rods is the new stainless steel type, which insures freedom from intergranular corrosion in weld metal even on crossed welds. The phenomenon in

* Presented at XIIth International Congress of Acetylene, Oxy-Acetylene Welding, and Allied Industries, London, June 6–8, 1936.

† Chief Metallurgist, Union Carbide and Carbon Research Laboratories, Inc.

question is related to a carbide precipitation at temperatures in the vicinity of 500 to 700° C. Titanium, tantalum and columbium tend to inhibit this carbide precipitation by preventing solution of the carbide. This is effected to the greatest degree by columbium, and the oxidizing tendency of the columbium during the welding operation is such that the material may be readily protected by reasonably small amounts of silicon. This is true to a much lesser degree in the case of tantalum or titanium, so that it is most difficult to obtain sufficient amounts of these materials in the deposited weld metal in an unoxidized state. The net result is the 18 per cent chromium and 8 per cent nickel, low-carbon type of welding rod with columbium in sufficient amount to combine with the carbon and keep it out of solid solution, and with sufficient silicon to protect this columbium during the welding operation. Approximately 1.0 per cent columbium and 0.75 per cent silicon are used.

Although an attempt is made with all the high alloy welding materials to get sufficient fluxing action with manganese and silicon, this is generally difficult because of the large quantities of chromium and other refractory oxide-producing elements present; accordingly a flux is commonly used. The major function of the flux is to dissolve the oxide on the base metal but it further aids in obtaining the desired viscosity of the slag covering on the weld proper.

Silicon and Manganese in Welding Electrodes

Much has been said to the effect that small quantities of silicon are undesirable in plain carbon welding electrodes, both bare and covered, in that they give rise to porosity in the deposited metal. That welding electrodes with silicon in the range of 0.20 per cent have resulted in porous welds is not to be questioned. Neither is it to be questioned that welding electrodes with the identical amount of silicon have resulted in very sound welds, and that these welds have had better physical characteristics than silicon-free welds made under the same general conditions. It is well known that silicon may increase the amount of gas held in solid steel, whether this be in the form of oxides which may later react, or dissolved gas as such, or of gas occluded on the surface of silicates. With properly made steel, the amount of gaseous element held in the steel is greatly reduced, and the writer knows of no instance in which such steel has given rise to porosity in welds made with reasonably good, normal technique.

The emphasis on manganese rather than silicon as the main deoxidizer in heavily coated electrodes is worthy of comment. Generally, the manganese is introduced into the operation as a ferro-alloy contained in the coating; but this coating almost invariably consists largely of silica in one form or another, so that even in this application the principle of the mutual fluxing action of the manganese and silicon oxides is utilized.

Cast Iron Welding Rods Improved by Alloys

In the welding of cast iron, alloy additions are used to increase the fluidity or to increase the strength, as the cast iron proper contains sufficient silicon for effective deoxidation. Phosphorus greatly assists the fluidity. Cast-iron rods with high phosphorus have a melting range so much lower than that of ordinary cast iron that the welding operation with such rods almost becomes a brazing operation. However, the physical properties of the deposited metal are relatively poor, because the phosphide eutectic that is formed imparts brittleness.

Of the strengthening elements, nickel, molybdenum and chromium are general, the nickel resulting in a strengthening of the ferrite matrix, and the molybdenum or chromium resulting in an iron with a strong tendency to become pearlitic. Other alloying elements have not yet been commercially used in cast-iron welding to any great degree; but new and improved types of cast-iron rods may be expected with the newer understanding of the metallurgy of this ancient product.

Early Developments in Copper Rods

The early welding of copper presented many problems, mainly due to oxidation and deoxidation. Although considerable information was available regarding the effect of a reducing atmosphere on the strength and ductility of oxygen-bearing copper, the relationship of this phenomenon and the results obtained in copper welding were not appreciated for some time. The early records show that investigators realized the need for some corrective for copper welding in order to improve the low physical properties of the joint.

Probably the first improvement to give consistent results is represented by the silicon-copper welding rods containing from 0.01 to 0.05 per cent silicon, together with small amounts of other metals generally considered as impurities. As poor joints still resulted from the reduction of copper oxide in the copper parent metal, the use of proper parent metal, generally deoxidized with silicon or phosphorus, soon became mandatory. High-strength, high-ductility joints were then regularly achieved when rods of increased silicon content were used. At this time, both silicon and phosphorus came into general use in the copper rods. Silicon has many advantages over phosphorus, chiefly in that the flowing quality is improved and the tendency toward porosity in the deposited metal greatly lessened. In fact, the characteristic of silicon in copper by which it tends to hold dissolved oxide in solution during solidification of the alloy eliminates gas formation and results in perfectly sound deposited metal. Today, it is present in amounts over 0.05 per cent in all high-quality copper welding rods. Phosphorus entails a great disadvantage, in that if iron is present as one of the components of the joint a brittle iron phosphide is formed at the interface and the strength of the joint is very low indeed.

Aluminum might also be used for deoxidizing copper or brass rods and would in a measure produce the same results as the silicon. However, the difficulty in fluxing the oxide, the inability to use such material in connection with iron or steel and the difficulty in obtaining material of precise analysis mitigate against its use, so that silicon remains as the outstanding alloying addition for copper welding rods.

Silver should be mentioned in this general connection, as it results in excellent fluidity and good strength in the deposited material. In general, however, the cost of this addition does not warrant the results, particularly as silicon is entirely satisfactory.

Modern Copper-Base Rods Further Improved

Copper welding rods with further improved characteristics have been developed in more recent years. Silicon is present in practically all cases, and copper-silicon may be considered the base of alloyed copper welding rods just as silico-manganese is the base of the alloyed steel rods. Among the elements added to this copper-silicon base, manganese, zinc, tin and iron are common. In the case of manganese, the same principle is applied as in the case of steel. The oxidation products of manganese and silicon are readily fusible and fluxed to the surface of the molten metal. Iron tends to reduce grain size on solidification and cooling, zinc promotes the formation of the strong beta constituent and tin further contributes to the strength of the matrix.

In the case of brasses and bronzes containing zinc and tin in addition to silicon, the differential oxidation of the silicon with respect to the zinc, together with the presence of the very thin slag covering, results in practical elimination of zinc oxide fumes.

In the welding of copper fusion welding and bronze-welding are to be considered. An alloy containing 2.5 to 3 per cent tin, with 0.08 per cent phosphorus or 0.05 per cent silicon, gives the desired welding characteristics if zinc in the welding rod is to be avoided. If zinc can be used, however, a 59 per cent copper-brass rod containing approximately 1.0 per cent iron and 1.0 per cent manganese, with 0.10 per cent silicon, is to be preferred. The most recent and probably the most satisfactory of the copper-zinc type of welding rods contains iron and tin at about 1.0 per cent, with silicon and manganese at approximately 0.06 per cent. This rod results in deposited metal having better than 55,000 lb. per sq. in. tensile strength and excellent ductility. For the sake of completeness, mention should be made of the great lowering of the melting range of copper by additions of larger amounts of phosphorus, particularly in combination with smaller amounts of tin. This effect has been utilized to produce a low temperature brazing rod. Again, leaded tin-zinc bronze for anti-friction service is made suitable for deposition by the protective action of silicon. It is probable that the presence of dispersed sub-microscopic silica particles in the deposited metal accounts for the absence of lead liquation during the process.

To summarize, silicon occupies a unique position in the welding of copper alloys. It acts primarily as a deoxidizer and fluxes with copper-tin and zinc oxides; it results in liquid metal of desirable viscosity; it holds gases in solution during solidification, thus promoting sound welding; and it almost completely suppresses zinc oxide fumes. Moreover, when silicon is used in connection with manganese, the resulting slag fluxes readily with the commonly used boron-oxide base flux, thus permitting the use of this material in brazing as well as in welding operations. Its availability and low cost help to insure its position in this field.

Silicon Also Important in Aluminum Rods

In the welding of aluminum, the temperatures are much lower than those required for copper or steel welding, and the difficulties are of an entirely different nature. Strangely enough, in spite of these differences the prime alloying element for improved welding is again silicon. When silicon is added in amounts greater than 2 per cent, the melting point of the alloy decreases, the freezing range widens, and the tensile strength increases appreciably. With 5 per cent silicon, the above effects occur to a still greater degree, and the 5 per cent silicon-aluminum alloy is extensively used for the welding of aluminum and aluminum alloys.

Possibly, the greatest single effect of the 5 per cent silicon is the reduction of internal stress during and immediately after the welding operation. Although the solid aluminum-silicon alloys have a lower specific gravity than aluminum, these same alloys in the liquid phase have a greater specific gravity. This is probably because of the expansion of silicon on freezing—an attribute valued to its fullest extent in the die casting. This lack of normal contraction on freezing diminishes the internal stress, and this reduction of the internal stress is particularly valuable in welding aluminum alloys which are frequently brittle at moderately elevated temperatures. This is particularly true of the high-strength aluminum alloys, which depend on precipitation hardening for their desirable characteristics. In these alloys, the carefully performed, age-hardening treatment is destroyed by the welding heat, and stresses accentuated by the volume changes accompanying these phenomena tend to cause cracks next to the weld. The expansion of the aluminum-silicon deposited metal on freezing reduces the magnitude of these stresses sufficiently to eliminate the formation of such cracks. Naturally, no element in the welding rod will eliminate the need for subsequent heat-treatment of the aluminum alloy, and the joining of precipitation-hardening aluminum alloys without local reduction of the physical property values is still a problem for the future. However, heat-treatment after the welding operation is frequently feasible, and restores the original structure and properties.

Because of the soundness of the weld obtained with silicon-aluminum alloy rod, this rod is also used for joining aluminum alloys which are not of the precipitation-hardening type, as well as pure aluminum sheet. When applied to the latter, the operation is almost that of brazing, as the low melting point of the alloy (575° C.) is a distinct contrast to the melting point of the aluminum base (668° C.). While the tensile strength of the silicon-aluminum deposited metal may be somewhat less than that of the high strength aluminum alloys, the ductility is good and the use of sufficient reinforcement generally results in a joint having a total strength equal to that of the parent metal. Moreover, in the welding of the high-strength aluminum alloys, alloying elements similar to those employed in the parent metal proper are frequently used in addition to the silicon; and these elements—such as magnesium, manganese and copper—are generally added to the welding rod slightly in excess of their amount in the base metal in order to compensate for losses by oxidation during the welding operation.

In welding aluminum, the removal of the readily formed oxide is a major point to be considered. The prevention or the removal of this oxide is generally accomplished by the use of added fluxes. Although various attempts have been made to produce a less refractory oxide by the addition of magnesium, lithium and similar very strong deoxidizers to the rod in order to form low-melting solutions or compounds of the aluminum oxide, no commercial success has as yet resulted from this line of attack. Silicon remains the outstanding alloy addition for aluminum welding rods.

Summary

Silicon, manganese, chromium, nickel, molybdenum, zirconium, phosphorus and columbium comprise the more important alloying elements in the modern, improved welding rods.

Of these, silicon is outstanding for its deoxidizing action in steel and copper welding and for its alloying benefits in aluminum welding. Manganese gives additional deoxidation, and the manganese oxides form desirable slags with silica. Chromium, nickel and molybdenum strengthen deposited ferrous metal, and zirconium is an almost universal cleansing agent. Phosphorus produces fluidity both in cast irons and copper-base alloys, and columbium removes carbon from solid solution in chromium-austenite. These are the major effects.

The above-mentioned elements and principles properly applied—singly or in combination—have resulted in major technical and commercial achievements. While the art of alloying is old, the science is young and ever-developing. We may well look forward to important additions to the above list, with new combinations. Further improved properties are to come, and with them the technological world will receive ever-increasing service from fusion welding.

Modern Day Welding in the Automotive and Railway Field*

By J. W. MEADOWCROFT†

BEFORE entering into a discussion of modern welding methods, as applied to our industry, I should like first to give you a little of the history leading up to these modern methods.

Since the time our company was first organized, we have been large users of all kinds of welding processes. These include arc, gas, flash, resistance spot, seam and projection welding. In the early days of our operation, arc and gas welding constituted the majority of the welding done in our plant. Today, however, we find that whereas we are still large users of gas and arc welding, the various forms of resistance welding provide one of our major fabricating tools. There are at least two reasons for this increase in the use of resistance welding. First: In a large number of instances it provides a cheaper, quicker and more flexible means of fabrication. Second: It lends itself more readily to a better maintenance of the finish and appearance, which is so necessary to the type of product we manufacture.

A survey of our fabrication methods today shows that spot welding leads all other methods by a large majority, both as to number of operations and investment in equipment.

Since the time our company was organized, and up until just a few years ago, the majority of this spot welding was done on stationary hand operated machines. In those days, the thickness of the material to be welded was comparatively light, so that low pressures and small welding currents were sufficient to do a satisfactory job. There was one disadvantage to this method, however, and that was that the product to be welded must be carried to the machine. This, of course, meant higher handling costs and usually lower production speeds. With this in mind, we set about to relieve this disadvantage by bringing the welding machine to the work. This was done with the full knowledge that under the system of what is now called portable welding, we would encounter other difficulties, such as higher maintenance costs. It was thought, however, that these difficulties could be more readily overcome, than the other difficulties of higher handling costs and lower production speeds. It was then that we designed and built our first portable welding machines.

This original machine was similar in many respects to the machines which we now have in our plant. It consisted of a welding transformer energized from a magnetic contactor; the welding being accomplished by means of a hand operated welding tool. The duration of the welding current was determined by the operator's push button, and the amount of pressure applied at the electrodes depended on the amount of pressure the operator applied to the tool with his hands.

The welding results obtained with this new set-up were no better than with the stationary machine, although handling costs were reduced and production speeds increased. We continued to get a certain percentage of broken welds which we were forced to repair.

It was felt that this trouble could be relieved, if not entirely eliminated, through a more accurate control of the welding time and the electrode pressure. These portable set-ups were, therefore, equipped with air operated portable welding guns and a welding timer of one of the several commercial makes. This marked another step forward in the development of spot welding, whereby a marked improvement in the quality of our welding was effected.

There were other types of portable welding, such as bar welding, wherein the transformer was mounted underneath the welding jig and the terminals of the transformer connected to a copper bus bar structure which constituted the jig. The single bar of copper was provided as a welding tool, and the weld was made by bridging across the copper jig with a welding tool, causing the current to flow through the pieces of metal to be joined. This type of welding is still in existence, with various modifications.

Portable welding, in one form or another, has during recent years, replaced just about all of our standard spot welding operations. The difficulties with this method of welding were present to an even greater degree than we suspected. The maintenance cost of this type of equipment is tremendously more than on stationary equipment; just the same as all portable equipment, whether it be for welding or other purposes, is more costly to operate than stationary equipment. We found, however, that the other advantages to be obtained far outweighed this disadvantage, for by means of this new method we were able to drastically improve our production methods.

Before portable welding was available as a commercial method, a large number of our operations were accomplished by means of gas or arc welding. This necessitated, in a large number of instances, that the excess of deposited weld metal be ground away, meaning, of course, another operation and an added expense to the cost of the product. In addition, this welding put into the metal considerably more heat than was actually necessary for joining the parts together. The excess heat, therefore, spread through the metal, causing shrinkage and discoloration, which must be removed.

In the earlier days of our automobile door construction, the "clinch" weld, which holds the outer door panel to the main structure of the door, was made by means of gas welding, which caused considerable trouble from the two causes mentioned above. It was then decided to spot weld this flange, but it was found that under the ordinary spot welding methods, a rather severe indentation was left on the outside panel of the door. This was,

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of course, out of the question, so it was then decided to attach one of the welding electrodes to the main body of the door, and the other electrode, in the form of a welding tip, was made to contact the inside surface of this joint. In this way, a satisfactory weld was made, with no marking whatever on the outside surface of the door. This operation was first done on a single spot stationary machine, but at the present time it is being done on another type of stationary machine, which is even more important to our welding operations than the portable spot weld.

This type of machine is commonly known as the Hydromatic Spot Welder, although various trade names have been applied to other modifications of the same general idea. Whatever name is applied to the machine, the operation is essentially the same. Such a machine will consist of as many separate electrode tips as there are welds to be made. These tips are located in the machine in such a manner that when the assembly which is to be welded is placed in the machine, the tips are at the proper location for making the desired welds. Each of these tips is operated successfully by a hydraulic pressure system, through a distributor valve. The welding power application is synchronized with this hydraulic distribution system, so that the current can be applied only after the pressure is applied to the electrode tip. In practice, the operation of this machine is such that the operator places the work in the jig and closes the push button, which starts the machine through its' cycle of operation. First, the ram of the machine operates to bring the various electrodes into position. This operation subsequently starts the cycle of pressure and power application to the electrodes, causing the welds to be made at first one point and then another, until all such welds have been made.

This machine can be adapted to almost any type of spot welding operation. For several years now, we have used this machine in the above mentioned "clinch" flange operation on our automobile doors. In this application one terminal of the welding transformer is connected to the main body of the door, and the other terminal of the transformer is connected to a main bus which supplies power to the 33 electrodes, spaced uniformly around the edge of the door. It is not necessary in this case to make the structure of the jig of copper, since the jig itself is not required to conduct any welding current. We have adapted this type of machine to various other smaller jobs in our plant, wherein there are only four, five or six such electrodes to each machine. Just recently, however, we have installed two such machines on a very much larger scale. This particular machine was designed and built for welding cover plates to the channel section, which forms the side rail of an automobile chassis frame. The machine, itself, is used first as a jig to align the two parts to be welded and to hold the proper shape. Secondly, it automatically performs the welding operation, which was formerly accomplished by means of portable welding tools. Each machine has a total of approximately 215 separate welding guns, which operate independently to make the various welds. In each of these welding guns, there is an upper and a lower electrode, operated by means of hydraulic cylinders, supplied through the pressure distributing mechanism from a central oil pump. The welding power for these electrodes is supplied by eight separate welding transformers, located in the base of the machine. Timing of the power application is effected through one of the less expensive types of tube timers. This timing is synchronized with the electrode pressure application, so as to give the proper cycle of pressure and current at the welding electrodes. These operations are so synchronized, and the timing is such, that very high production speeds are permissible. For example, in each of these machines, production speeds of 120 pieces per hour have been obtained. This, of course, permits an appreciable saving in production cost, and also produces a more uniform product, from a standpoint of quality, as well as appearance.

As I have said before, spot welding provides a very flexible means of fabrication. By that I mean that it can be adapted to do almost any job. In certain cases, however, the job may be such as to render the cost of spot welding much greater than some of the other welding methods. In those cases, we, of course, avail ourselves of the cheaper means.

One disadvantage to ordinary spot welding is that it leaves an indentation on each surface of the welded piece, but it is perfectly possible to minimize this objectionable marking, on one surface only. This marking may be minimized by using a large flat electrode on one surface and a relatively sharp pointed one on the other, but even so there will usually be some marking due to shrinkage of the welded material. One very satisfactory way of partially eliminating this effect is to make the flat electrode slightly concave. This will cause the weld metal to assume this shape, so that it sticks up above the surrounding metal, and may be ground down to present a smooth appearance. This method has been applied to several jobs with very satisfactory results. It is, of course, more expensive than the usual spot welding operation, but in many cases this added expense can be justified.

Projection welding provides another very important fabrication tool. As you all no doubt know, this welding is accomplished by forming a projection on one of the pieces to be welded and making the welding current flow through the projection, fusing itself to the other piece of material. Although this welding is not as universally applicable as spot welding, it is even more economical in those instances where it is applicable. The reason for this is that electrode maintenance is considerably reduced because we use a large flat electrode instead of the pointed one. Also, this method lends itself more readily to multiple welding. In our plant, we use it to a rather large extent in sub-assembling small pieces to a larger piece.

Seam welding is also used to some extent in our plant. This welding, as you all know, is accomplished by making a series of overlapping spotwelds, so as to produce a continuous band of welded metal. This has been used to very great advantage in our stainless steel work in the construction of such products as gasoline and water tanks and water and air tight bulk-head doors.

Flash welding, which is sometimes referred to as butt welding, also plays an important part in our operations. We now have in one of our automobile door production lines, nine flash welders, with which we build up the door from smaller metal stampings.

In the earlier days when the steel mills were not equipped to make the large sizes of sheet steel which we required for our work, we designed and built a flash welder capable of joining two smaller sheets to form the required dimensions. This machine was capable of flashing a 120-inch seam of 0.043-inch thick steel, and remained in operation until a few years ago, when the steel mills discontinued the premium applying to these larger sheets.

Flash welding is also put to other important uses, such as the joining of two component body parts which would be difficult, or even impossible to form as a single piece. After the "flash" has been removed by a grinding opera-

tion, the resulting surface of the metal leaves no indication whatever of the welded zone.

In discussing the various methods of spot and flash welding, I do not wish to leave the impression that arc and gas welding has been relegated to the background. This is not the case, for we are still large users of both arc and gas welding in our production set-up. This is evidenced by the large amount of oxygen, acetylene and arc welding wire which we buy for our production and maintenance operations.

Gas welding is likewise of major importance for certain cutting operations, which would otherwise entail a tremendous amount of time and trouble, if this more efficient means were not available.

This development of welding equipment and methods, throughout the past years, has been followed by development of a more specialized field of resistance welding, enabling us to safely and satisfactorily spot weld stainless steel. This development was started some six or eight years ago, when practically all fabricators who had tried welding this material, met with no success whatever. They found that this relatively non-corrosive material, was no longer corrosion resisting, in the neighborhood of the weld. It was felt by our engineers, that this difficulty could be overcome, and it was this thought in mind that led us to the development and application of our present "Shotweld" process. This process is spot welding. However, it involves much shorter weld times, a much higher current and more accurate, precise control of both the higher weld current and shorter time. At the time our "Shotweld" process was invented, equipment which would produce the required welding results was not readily obtainable. We developed our own equipment and found it of greatest expediency to continue this development. We now have, in operation in our plant, numerous machines of our own unique design. This machine was constructed along mechanical lines and had great repetitive accuracy in the timing of the welding period. It gave highly satisfactory results from the outset. There followed development of our present welding recorder. This consistently compares each weld with each other weld.

The design of this instrument is that of a ballistic wattmeter, except that the characteristics are changed somewhat. The deflection of the meter is proportional to the square of the welding current, and to the time during which this current flows. This instrument gives a proportional measure of the amount of heat generated in the weld, and any variation in this amount of heat, which will naturally affect the quality of the weld, is immediately indicated, both visually and audibly, as well as recorded, by the weld recorder.

This instrument is now a standard feature of all of our stainless steel welding machines. Up until the present time, there has been no application of the recorder, in connection with our spot welding operations, due to the fact that ordinary material is not nearly so harmfully affected by variations in time and current, as stainless steel, also to the fact that we have a larger factor of safety with respect to weld strength in our automobile work. There are certain automobile body operations, however, on which we believe the recorder will prove of valuable assistance. These applications are now being considered with a view to using the recorder on them.

The foregoing will, I hope, give you a fairly complete picture of the development of our welding equipment. These changes and developments have caused, or rather permitted, corresponding changes in our production methods. The fact that we can now bring the welding machine to the work, has been a tremendous improvement. In fact, certain of our assembly operations would be entirely impossible, if it were not for this type of welding.

The automobile industry has long since adopted as standard practice the method of fabrication, by means of sub-assembly. In fact, the automobile industry was practically the instigator of this system. This system is now being inaugurated, in connection with the fabrication of our stainless steel structures. During the early stages of this development, our fabrication was accomplished in very much of a custom made manner. In other words, each article was built from the ground up, with few possibilities of utilizing any sub-assembly operations. This was brought about by the fact that the amount of production which followed, did not justify any serious consideration of such a possibility at that time. With the rapid growth of this phase of our industry, we find some more simple means of assembly is demanded.

We now have in the process of construction, in our plant, about eighty light weight streamline rail cars. Twenty of these cars are just about completed, and in all of them, we have broken down the main assembly operation into numerous sub-assemblies. For example, the side frame structures of these cars, although they are not exact duplicates of each other, are enough alike to permit the use of one jig for the construction of all of them. The various parts constituting this sub-assembly are clamped in place, and the welding operations begin. The same type of sub-assembly is used in the construction of the roof, end frames, the floor girders and center sill, and numerous other smaller parts constituting the main assembly. These relatively large sub-assemblies are, in turn, broken down into smaller assemblies. Some of these smaller assemblies may consist of only two or three welds, fastening one small piece to another, but where numerous of these small pieces are necessary to the construction of the train, it is absolutely necessary that some systematic order of fabrication be followed.

In all of these assembly and sub-assembly operations, welding plays a very important part. We feel that this means of fabrication is so important to our operations that we must be ever alert to new applications, and maintain a continual development of the various processes and the equipment necessary to them. The advancement in resistance welding throughout the past few years, has been so rapid, as to make last year's welding machine almost obsolete for this year's production. It is, therefore, necessary that any equipment involving an appreciable amount of money must be so designed as to be extremely flexible in its application. If this were not possible, the cost of welding equipment would be considerably higher than it is.

Continual changes in the design of the product also demand a very flexible machine design. For example, the investment in an automatic welding machine is such that its basic design must be such as to allow for rather drastic changes in the design and shape of the piece to be welded. Even so, the cost of changing over some of these larger machines to meet new production conditions is quite high, yet only a fraction of the original cost of the machine.

Welded Boiler Drum Practice*

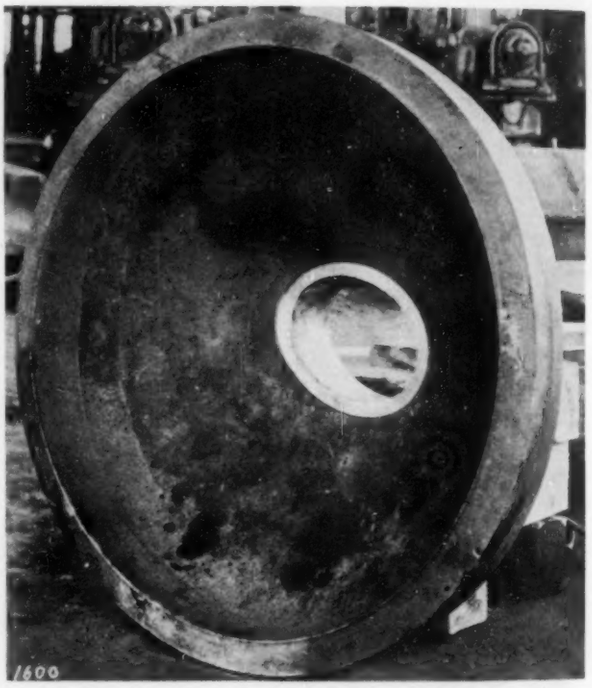
By A. J. MOSES†

A FULL discussion of this subject would cover designs, materials, construction and testing procedures. A brief description of accepted materials, of standard methods of construction and control, and of present trends is all that can be attempted in the time allotted. Methods of construction and testing will be treated jointly as these actually are and should be inseparable factors in welded boiler drum practice. Also, the discussion of these factors will be more intimately related to the more advanced applications in the high pressure field.

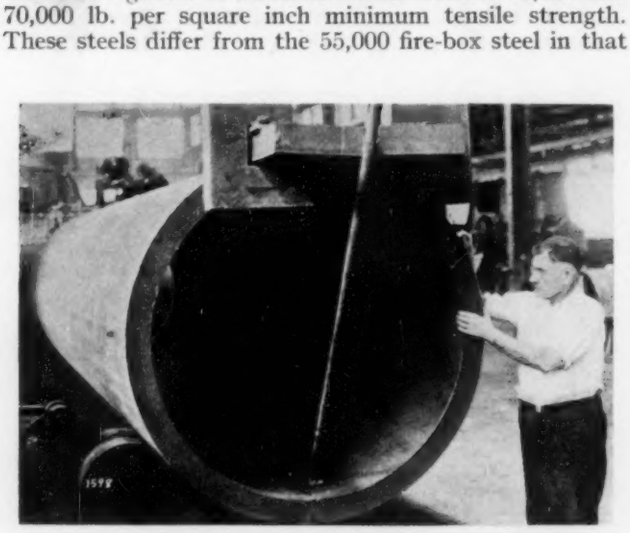
The safety of welded construction was amply provided for before authorization was given its use. Therefore, no experimentation has been perpetrated on the users of welded boiler drums. Uniform and reliable methods of testing were first evolved. A standardization of welding techniques naturally followed. This happy situation was largely accomplished through the agency of our principal governing body over such matters in this country, the A. S. M. E. Boiler Code Committee.

This committee first authorized welded construction in boiler drums in June 1931. At that time it issued its welding code, allowing a 90% weld joint efficiency where such joints met all the specified requirements. No change was made in the established design factor of safety of 5 and no change was made in plate material specifications.

Welding fabricators, therefore, were restricted to the use of fire-box quality steel of 55,000 lb. per square inch minimum tensile strength. In order to meet an increasing demand for higher pressure boiler drums, involving heavier plate thicknesses and higher tensile strength steels, the Committee has investigated and approved the use of two grades of modified carbon steel of 65,000 and 70,000 lb. per square inch minimum tensile strength. These steels differ from the 55,000 fire-box steel in that the carbon and manganese contents are higher, being limited to 0.35% and 0.90%, respectively. These steels are now in general use in the construction of welded high pressure boiler drums.



Semi-Elliptical High-Pressure Boiler Drum Head



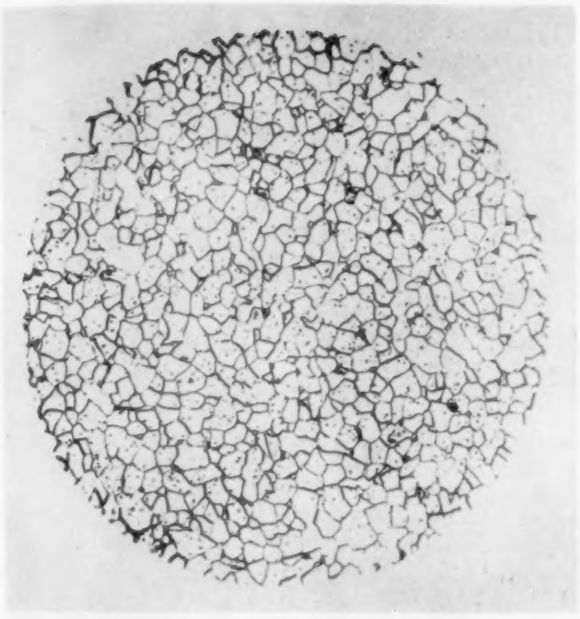
Fusion Welded Boiler Drum Shell with Attached Sample

Boiler plates up to 5 inches in thickness are now being employed in the construction of welded boiler drums. Where thickness exceeds 2 inches, a normalizing heat treatment is applied to flat plates before forming, for grain refinement. Also, a subsequent drawing treatment is sometimes given to facilitate the forming operation when this is to be performed cold. The shaping of these heavy plates is done under hydraulic presses. This necessitates the use of two longitudinal seams. Since intermediate girth seams are not desirable in this type boiler drum, the shells for same are composed of two plates, each formed to approximate half circles. Shells exceeding forty feet in length have been constructed by this method.

For reasons of economy, unequal thickness plates are frequently employed in such drums, the heavier section designed for areas to be perforated with tube holes and the lighter for unperforated sections or sections having a greater tube hole ligament efficiency. In this construction the heavier plate is tapered by machining to the thickness of the lighter, the machining being done so as to make the neutral radii equal and the neutral circumferences coincident. This planing operation, together with the machining of weld grooves, is usually performed

* Presented at the Pittsburgh Round Table Discussion of the World Power Conference, September 4, 1936.

† Hedges Walsh Weidner, Division of Comb. Engrg. Co., Inc.



Micro-Structure of Fusion Weld Metal—250 Diameters

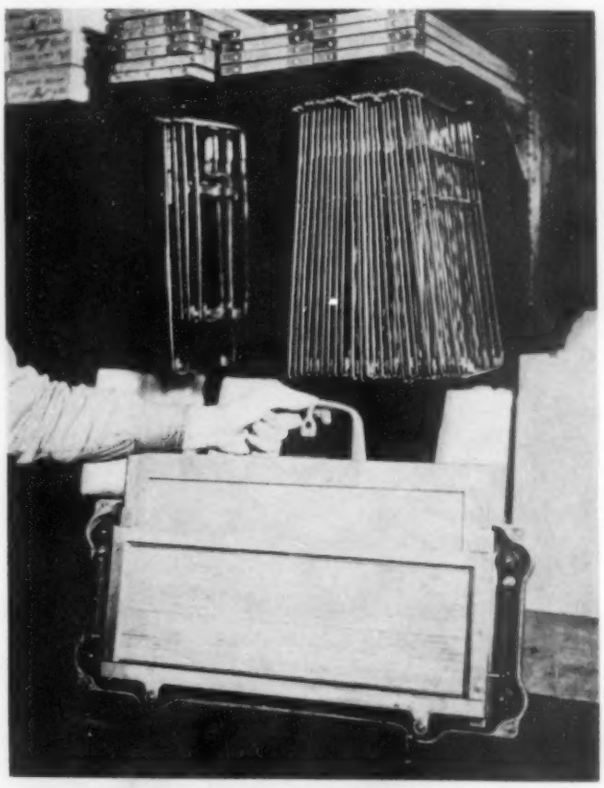
after the plates have been formed into half cylinders. Similar machining of shell thickness down to head thickness and preparation of the girth weld grooves is usually done after the completion of the longitudinal seam welding.

The electric metallic arc method of welding, using heavily coated electrodes about $^1/_4$ inch in diameter, is the accepted practice. The design of weld joints for all main seams is the double butt type. Fillet welding is only permitted in the welding of nozzles, reinforcements and other external and internal attachments. All welding is done in the down-hand position, the drum being slowly rotated to accomplish this when welding the heads to the shell.

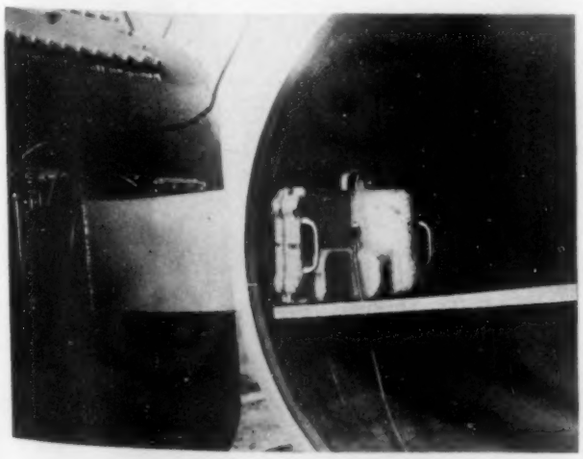
Weld metal is deposited in the grooves in relatively thin layers. The process leaves a heavy slag coating over these layers. This slag is thoroughly cleaned from each layer before depositing the succeeding one. Also, each bead is inspected for the removal of defects which cannot be eliminated in the succeeding operation. No actual peening of the layers is ordinarily necessary. However, peening is sometimes desirable under extreme conditions for the purpose of counteracting warpage and curtailing dangerous stresses pending thermal stress-relieving.

In finishing double butt welds, a small reinforcement of deposited metal is added to both sides of the plates. This reinforcement is subsequently chipped off and the surfaces ground practically flush with that of the plate. The purpose of this reinforcement is to obtain a full thickness section of refined weld metal. The excellent physical properties of such type joints are largely due to to the heat treating effect on preceding layers from subsequent depositions. After serving this purpose the reinforcing layers are removed from butt-weld joints as this added metal interferes with X-ray examination.

In connection with the welding of longitudinal seams, attached samples are used for the purpose of checking the physical properties of the weld joint against standard



An Industrial X-Ray "Bucky" Diaphragm, Cover Plate Removed, Showing Thin Strips of Lead Spaced with Strips of Wood

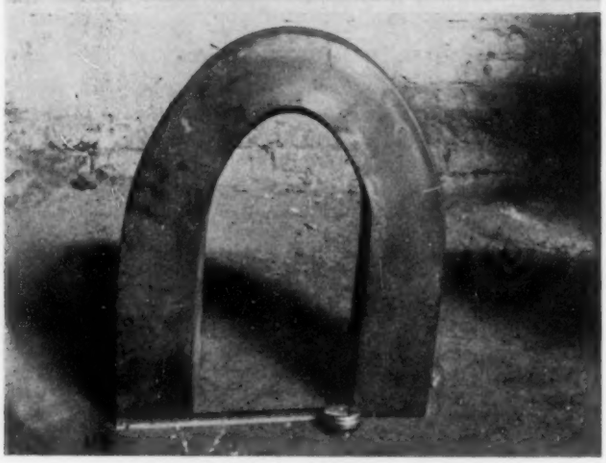


Taking X-Ray Picture of Longitudinal Weld Seam

requirements. The welding of these samples is a continuation of and an exact duplication of the welding procedure used in the actual seams. After stress-relieving, such samples are tested for tensile strength and ductility. Minimum results have been established for transverse bend and tension specimens, and also for all weld metal ductility and tension coupons.

No physical test samples are required from the head girth seam welds, provided same have been obtained from the longitudinal seams. Semi-elliptical shaped heads are used in the construction of high pressure boiler drums. Also in this field, a welded manhole reinforcement type of construction is often used which radically differs from the flanged in type of construction. In the former a dished reinforcement plate is welded to the head around the manhole opening, using a single groove and a fillet weld on the inner and outer seams, respectively.

Macro Section of Fusion Weld Joint



Bend Test of 4-Inch Thick Weld Specimen

Many precautions are taken to insure the quality of weld joints in boiler drums. The materials used and the processing of the coated electrodes is carefully controlled and checked. Operators are thoroughly trained and properly qualified. The preparation of the work for welding and the welding operations are under the constant supervision of competent inspectors. Such control is important but not satisfying. Deposited metal, like parent metal, requires more than faith in a manufacturing technique as a basis of acceptability. It was for this reason that the Code Committee would not allow welding in boiler drums until a reliable non-destructive test was developed to supplement the physical tests of attached samples.

All main seams—that is, butt-welded joints—in boiler drums are subjected to X-ray examination. A radiograph of eight to fifteen lineal inches of weld joint is obtained per exposure. An image of a permanent marker placed on the work is obtained on the film, so that these can be readily matched. A sensitivity gage placed on the work affords means of controlling X-ray technique. All defects not within acceptable allowances are chipped out, repaired and re-X-rayed. The films, constituting a permanent record, are kept on file for a number of years.

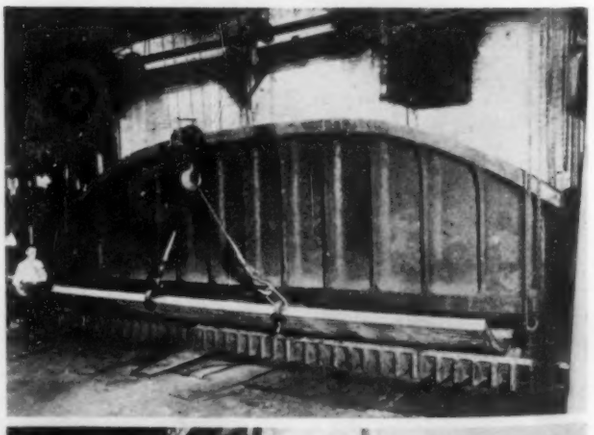
Following the X-ray examination, completely welded drums are thermally stress-relieved in large annealing furnaces. The vessels are gradually brought up to a temperature of 1100 to 1250 degrees Fahr., held at temperature for one hour per inch of thickness, and furnace cooled to about 500 degrees Fahr. before removal. Furnace and work temperatures are held under fairly close control to avoid distortion of vessels. There is very little danger of this occurring in the stress-relieving of heavy wall boiler drums if they are properly supported.

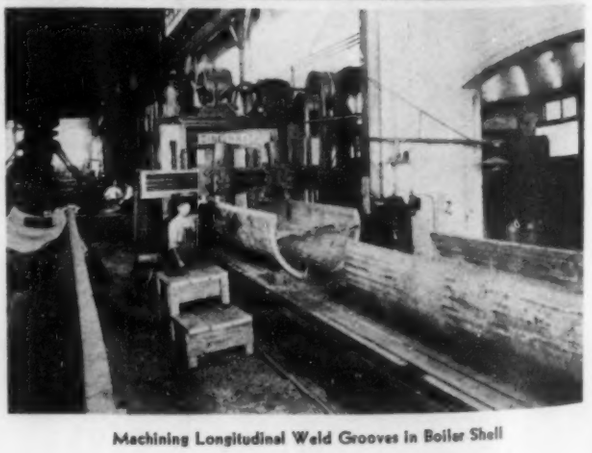
Stress-relieved vessels are hydrostatically tested to twice the design working pressure. While under pressure, the weld seams are given a thorough hammer test, the weight of the hammer and the force of the blows being so regulated as not to damage the surface severely. Following these tests, all machine work such as drilling, counterboring and grooving of tube holes, and the finishing of gasket surfaces, is completed. The drums are finally cleaned for inspection and the application of a surface protecting treatment.

Substantially as outlined above, fusion welded boiler drums have been constructed for steam pressures up to 1400 lb. per square inch. The diameters of these vessels have varied from 24 to 60 inches, and the lengths from a few feet to over 40 feet. The trend to higher pressures has brought about an increase in boiler plate thickness from $2^1/_2$ inches, the limiting figure in riveted construction, to 5 inches, the present limiting thickness in welded drums. The latter limit is set by radiographic considerations. 400,000-volt Coolidge X-ray tubes are now being used. A "Bucky" diaphragm for the elimination of scattered radiation is employed in radiographing sections over 3 inches. With its aid, reliable pictures can be obtained through 5 inches of steel. Over that amount, sensitivity is lost and the time of exposure becomes prohibitive. Heavier wall thicknesses are being used, up to 6 inches and slightly above, but in such construction seamless shell forgings with welded-on heads is the accepted practice.

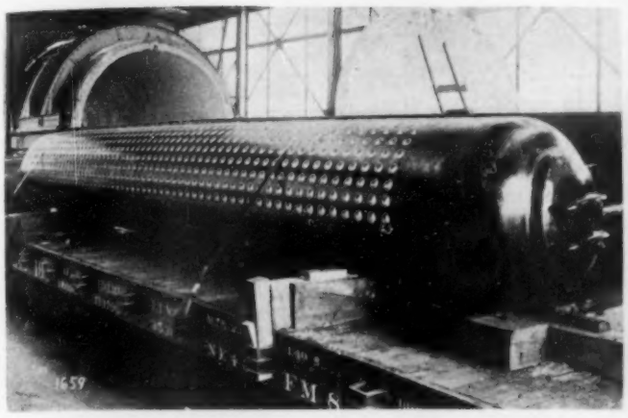
At present there is a demand for a reliable and eco-

Forming 5-Inch Thick Boiler Plate to 60-Inch Diameter





Machining Longitudinal Weld Grooves in Boiler Shell



Completed Boiler Drum Showing Welded Manhole Reinforcement

A Group of Boiler Drums Showing Thick and Thin Plate Construction

nomical extension of non-destructive testing to greater thicknesses and also for the approval of higher tensile steels. Some very promising preliminary fatigue tests have already been made on welded vessels fabricated of special steels of tensile strengths up to 85,000 lb. per square inch minimum. Present data indicates limitations in this respect will have to do with ductility requirements of base materials for this service. However, it is safe to predict that welded boiler drums of such higher tensile steels will be common practice within the next few years.

The art of fusion welding has met the physical and chemical requirements of the base materials now approved. That it can safely be applied to certain higher tensile steels is an assured fact. At the present time welded joints of ample ductility for this service and of 100,000 lb. per square inch minimum tensile strength can be produced economically.

Recent Welded Boiler Drum Practice—the Commercial Aspects*

By E. R. FISH†

THE rapid strides made in the development of steam turbines and the insistent demand by turbine designers for higher and higher steam pressures and temperatures is the basic cause for the great changes that have in recent years come about in boiler design and construction.

During this period of change, even with the relatively small drum diameters used with water tube boilers, plate thicknesses rapidly approached the practicable limit for riveted construction which is about 2 inches and there are very few shops that can fabricate such plates.

Not only have steam pressures and temperatures risen but the need for large quantities of steam from individual boiler units has reached the most astonishing figures. This factor has often necessitated exceedingly long drums that made riveted construction practically impossible.

In order to obtain boiler drums for the higher pressures, which required greater plate thicknesses, resort was first had to seamless forged drums manufactured in much the same way as large gun barrels. Indeed, such drums could be made only at two or three plants that were provided with gun making equipment. Drums made in this way were quite ideal so far as strength went, but they are exceedingly expensive, almost running capital expenditures into uneconomical figures.

Meantime, however, great progress was made in the technique of fusion welding and advocates of this process were finally able to demonstrate to the satisfaction of the AMERICAN WELDING SOCIETY and the Boiler Code Committee of the American Society of Mechanical Engineers, which is the generally recognized and accepted authority on boiler construction in this country, that acceptable welded joints, with respect to all the desirable physical qualities, could be produced. It is now exactly five years since the A. S. M. E. Boiler Code Committee in cooperation with the AMERICAN WELDING SOCIETY, promulgated definite rules for the construction of welded boiler drums and the substitution of welded for riveted or seamless construction has now become practically universal. There are between fifteen and twenty shops in this country equipped to build welded boiler drums strictly in accordance with the Code requirements.

Steam Pressures on the order of 1200 to 1400 lb. per sq. in. are very common in industrial as well as in public utility plants. Indeed there are several instances of boiler pressures of 1800 or more lb. per sq. in. Such pressures involve plate thicknesses up to $4\frac{1}{2}$ and 5 inches. Such plates must necessarily be formed by pressing instead of being rolled, even in drum lengths of about the 35 or 40 feet used in many large boilers.

The form of the welding groove, the nature of the electrodes, the technique and current characteristics, etc., used in depositing the weld metal have all been developed to the extent that strong, ductile and sound welded joints can be assured. The requirement that special test plates be made at the time the drums are welded, and from which specimens are cut and tested, demonstrate, with reasonable certainty, the physical characteristics of the

* Presented at World Power Conference, Round Table Conference, Pittsburgh, Sept. 4, 1936.

† Chief Engineer, Boiler Division, Hartford Steam Boiler Inspection & Insurance Company.

weld metal, while the required radiographic examination of the completed weld shows the presence of or freedom from serious defects, such as, gas pockets, lack of fusion and slag inclusions.

While the welding of the joints of boiler drums was primarily brought about by the need for heavy plates, the use of welding has been extended to the fabrication of boiler drums for more moderate pressures requiring only relatively thin plates. It may be said that there is comparatively little riveted boiler construction now being done in the shops of this country. This change from riveting to welding has meant large capital expenditures for equipment for welding, stress-relieving and X-raying which is necessarily accompanied by the obsolescence of much expensive riveting equipment that is very far from being worn out.

Riveted joints in boiler drums have always been subject to leakages and the source of various other kinds of trouble, one of the most serious of which is cracking between rivet holes. Many major failures because of cracked joints have occurred and great expense has had to be incurred, in numerous instances, to repair defects of this kind, even to the extent of replacing drums. In fact, the first welded boiler drum was one to replace a drum with the riveted joints found to be so seriously cracked that it was dangerous to continue it in operation. Welded joints are absolutely tight when made and remain so indefinitely. There are no discontinuities to cause concentrations of stresses of unknown distribution and magnitude such as inevitably exist in riveted joints and which undoubtedly contribute to the development of their characteristic troubles.

The desirability of getting away from riveted construction and the advantages of the welded joint have resulted in the almost universal specification, on the part of purchasers, for welded construction, irrespective of the plate thicknesses or pressures to be carried. With respect to the relative cost of riveted and welded work, it may be said that there is little, if any, difference.

Not only are the seams that join the edges of the plates together welded, but it is also the practice, under carefully prescribed rules, to attach by welding, outlet nozzles and any needed reinforcement of openings cut in the shell. Here again lies the advantage of obtaining steam tight outlets and leak-proof construction, much to the relief of the operating personnel.

The boiler insurance companies are strong proponents of welded construction from which the inference is obvious that they do not hesitate to afford insurance on boilers of this type of construction. There has not as yet been opportunity to get the test of time over long periods of operation, but there has not come to the writer's attention any failure of a welded boiler drum built in the last five years under the Power Boiler Code regulations.

Although the A. S. M. E. Code does not now sanction the welding of other than the cylindrical parts of boilers, there is a Committee charged with the study of the extention of the application of welding to other features of boiler design. This will probably include welding in of staybolts, the attachment of braces for flat surfaces, the welding of water wall and superheater tubes which often have to be of considerable length, etc., all of which illustrates the confidence that boiler manufacturers, boiler users and boiler insurance companies have in this type of construction. In addition, attention is called to the fact that the Boiler Inspection Departments of the various States of the United States do not hesitate to permit the use of welded boiler drums in their jurisdictions. They do require, however, that all such boilers shall bear the A. S. M. E. Code stamp as assurance that they have been built under proper supervision. The U. S. Navy Department also now specifies welded drums for the boilers of its ships of all kinds.

In conclusion let me call to your notice the very extended application of welding to the construction of pressure vessels of many kinds and used for a great variety of purposes. Fewer and fewer riveted vessels are being purchased. All of which, in connection with boilers, points quite conclusively to the general adoption of welding in the fabrication of all pressure vessels.

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(*Continued on page 27*)

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

Seventeenth Annual Meeting

The Seventeenth Annual Meeting of the AMERICAN WELDING SOCIETY held in Cleveland during the week of October 19th was, without doubt, from all viewpoints, the most successful ever held by the AMERICAN WELDING SOCIETY. A registered attendance of more than a thousand at the technical sessions surpassed all records. The program was crowded in some places, but ample opportunity was provided for discussion. Attention was called to the fact that written discussion of any of the papers may be sent in which will be reviewed and published.

An unusually interesting program of technical papers and research reports covering many important phases of welding was provided. The speakers were generally nationally known authorities on their subjects. The October issue of the JOURNAL, one of the largest published by the Society, was well received and attracted considerable favorable comment.

Inspection trips, the stag and the Annual Dinner of the Society were also well attended. Almost everyone present at this meeting was well repaid for the time they spent in attending the convention.

Members of the Society are cordially invited to read the Open Letter to Members signed by the President and published on the inside front cover of this issue.

The Exhibit surpassed all former displays of methods, materials and equipment. The exposition was held at the Lakeside Exposition Hall adjoining the Cleveland Public Auditorium. The technical meetings of the Society took place at the Hotel Cleveland.

Departing from previous custom the exposition was a closed shop being limited to persons directly interested in the display, except for the last day.

The technical session on the fourth day was held under the joint auspices of the Welding Society and the A. S. M. E. Members of the Welding Society visited the plants of The Lincoln Electric Company, The Wellman Engineering Company and the General Electric Institute.

Following are the names of the Cleveland Committee that acted as host to the Society on this occasion.

Messrs. E. T. Scott, Chairman in charge of local arrangements.

R. P. Tarbell, Chairman of the Cleveland Section also Chairman of the Reception Committee.

L. R. Berkeley, Acting Chairman of the Technical Sessions.

A. L. Pfeil, Chairman of Inspection Trip.

E. R. Benedict, Chairman of Exhibits Committee.

A. Arnold, Acting Chairman of Registration and Finance.

G. A. Maurath, Chairman of Entertainment Committee.

Mrs. R. E. Kinkead, Chairman of Ladies Committee.

Among the members who served with the above Chairmen during the week may be included:

Messrs. J. M. Driscoll, DeBloys, H. E. Westendarp, Fred Newton, Frank Boucher, Fossnacht, H. L. McCreery, J. T. Wolfenden, Otto Bornemann, N. J. Carbis, Thomas Lawless, Markee, Joseph Elsner, Al. Williams and Mrs. Morris Taylor.

New York Section Lecture Course Goes Over Big

The first Lecture dealing with the Fundamentals of Arc and Gas Welding and Cutting was delivered on Tuesday, November 10th before a crowded Auditorium at Brooklyn Polytechnic Institute.

Those that want to join the Course still have an opportunity. The other nine lectures will be presented by outstanding authorities. Almost any one would be worth the entire cost of the Course. The next two lectures are:

November 24—Metallurgy of the Welding of Steel, by J. C. Hodge, The Babcock and Wilcox Co.

December 1—Metallography of the Welding of Steel, by E. S. Davenport, United States Steel Corporation, Research Laboratory.

Plan to attend!

Filing Classification of Welding, Brazing, Soldering and Cutting Processes, Materials and Applications

This Classification prepared by a Committee of the AMERICAN WELDING SOCIETY may be used as either a filing system or an indexing system. When used as a filing system the folders are numbered and filed in accordance with the proper classification number. When used as an indexing system the folders may be numbered and filed serially and a card index maintained in accordance with the proper classification number or numbers.

A limited number of copies have been prepared in mimeograph form and are available at 50¢ per copy.

H. M. Hobart

Award of the Samuel Wylie Miller Memorial Medal. 1936 Recipient—Henry Metcalf Hobart

About nineteen years ago there came into existence the Welding Committee of the Emergency Fleet Corporation. Along with it there was organized a Welding Research Committee and Henry Metcalf Hobart was appointed its Chairman. In September 1917 Mr. Hobart went to London to study the applications of welding in the various yards of British shipbuilders, the Admiralty and private concerns. Mr. Hobart's report of this trip constituted the most comprehensive summary of the knowledge of the welding art available at that time. This marked the beginning of a research movement that has grown and spread to the four corners of the earth. There are very few of the earnest workers who were associated with these early endeavors who are still vitally interested in welding research. Fortunately, for the welding industry and for the AMERICAN WELDING SOCIETY one of these is our loyal friend who is still on the job.

If we were to "take a look at the record" we would find a surprising number

of Mr. Hobart's predictions made in those pioneer days that have come true. We would also discover that statements made most positively by some of our engineers and commercial men have been discarded. For example, the use of alternating current, covered electrodes and high current values are accepted facts.

The minutes of the monthly meetings of the Welding Research Committee of the Emergency Fleet Corporation form one of the most interesting historical records of early welding progress that is available.

The work of this Committee and its parent body, the Welding Committee of the Emergency Fleet Corporation, led to the organization of the AMERICAN WELDING SOCIETY and of the American Bureau of Welding, its research department.

Probably the most important committee of the Bureau of Welding is that on Fundamental Research of which Mr. Hobart has been the Chairman from the beginning, and it is largely through his untiring efforts that the number of research projects in this field has increased from a mere handful to more than sixty. These projects are being carried out almost wholly by professors in the various universities in the country. Probably no committee of the AMERICAN WELDING SOCIETY has been so productive of important contributions to the advancement of our knowledge of welding and the extension of its applications. Each year for quite a few years past these reports have constituted the most important papers presented before the Annual and Fall Meetings of the Society. Probably a great many members of the AMERICAN WELDING SOCIETY will be surprised to know that this was done with practically no funds. The enthusiasm, determination and courage of its Chairman, in the face of heavy handicaps, are largely responsible for the noteworthy contributions of this Committee.

It would be impossible to give a complete account of the numerous and varied activities of Henry Metcalf Hobart. He was born in Boston, Mass., 1868. He graduated from Massachusetts Institute of Technology and carried on a consulting practice in London from 1903 to 1911. He was Chief Designer of Continuous Current Machinery for the Union Electricitäts Gesellschaft of Berlin, and Technical Expert for the British Thomson Houston Company. He has been connected with the General Electric Company as an engineer from 1895 to 1900, and as Consulting Engineer from 1911 to date. He is author of a considerable number of books dealing mostly with electrical machinery and its applications.

Mr. Hobart is one of the founders of the Society and one of its Directors. He served as first Vice-Director of the American Bureau of Welding and has represented the Society on the Engineering Division of the National Research Council. He is a member of the Institution of Civil Engineers, and of the Institution of Mechanical Engineers of Great Britain; a Fellow of the American Institute of Electrical Engineers and a past Vice-President, a member of the American Society of Mechanical Engineers and of the American Association for the Advancement of Science.

However, the mere enumeration of these activities and contributions of service, however great, constitute no real measure of man. The majority of engineers work industriously and sometimes very effectively in their own interest or in the interest of their employers, but it is the exception when an engineer works for a cause or ideal with little consideration for material reward. Mr. Hobart is a very prominent example of such an exception. A hard and enthusiastic worker, an individualist in his methods with the highest ideals of his profession, he has brought to bear on all the problems which he has attacked an unusual fund of experience, as well as an unusually generous spirit of cooperation.

It gives the Board of Trustees great pleasure, therefore, to honor at this time one of our foremost pioneers in welding research—Mr. Henry Metcalf Hobart—who was so closely associated in the early days with Mr. Samuel Wylie Miller in whose memory the Medal has been established. The Board feels sure, also, that the Society will rejoice in giving recognition to one of its most faithful workers.

Board of Trustees
W. LUDINGTON, *Chairman*
C. A. ADAMS
H. L. WHITTEMORE

Lincoln Welding Handbook

The New Handbook, now in fourth edition, contains 223 added pages of new arc welding data and 289 new illustrations, including photos and drawings. The volume now contains 819 pages and 990 numbered text illustrations. The Procedure Handbook is $5^3/_4$ x 9 inches, an ideal size for desk or shop use. The binding is semi-flexible simulated leather, gold embossed. Copies ordered will be mailed, postpaid, to any address in the United States for $1.50 per copy. Outside United States—$2.00.

Orders may be placed through the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y.

Morehead Medal Awarded to Dr. D. S. Jacobus

The Morehead Medal for the year 1935 has been awarded to Dr. David Schenck Jacobus for his outstanding leadership in the formulation of codes and procedures which have made fusion welding acceptable. The medal will be presented to Dr. Jacobus during the opening session of the 37th Annual Convention of the International Acetylene Association to be held at Hotel Jefferson in St. Louis, Wednesday, November 18th.

The Morehead Medal is awarded annually by the International Acetylene Association to the person or persons who, in the judgment of its officers and Board of Directors, have done most to advance the industry or the art of producing or utilizing calcium carbide or its derivatives. The award was established in 1922 by the Hon. John Motley Morehead, formerly United States Minister to Sweden, in honor of his father, the late James Turner Morehead who, in 1892, sponsored the experiment which lead to the discovery of the electric furnace method of producing calcium carbide.

Dr. Jacobus is well known to members of the AMERICAN WELDING SOCIETY having served as its President during the year 1934–1935. He has been Chairman of a number of important committees of the Society and is Chairman of the Editorial Committee which has been largely responsible for the conception and planning of the proposed Welding Handbook. A complete biographical sketch of Dr. Jacobus is given on page 2 of the May 1934 issue of the Journal.

Lukenweld Elects Chapman President

Everett Chapman, who has been vice-president of Lukenweld, Inc., Coatesville, Pa., has been elected president of the company, according to an announcement by Robert W. Wolcott, president of Lukens Steel Company, of which the Lukenweld organization is a division. Chapman succeeds G. Donald Spackman, who was recently promoted to General Superintendent of Lukens Steel Company.

Robert J. Whiting, who has been superintendent of Lukenweld, Inc., in charge of all manufacturing, has been elected vice-president of Lukenweld, Inc.

Mr. Chapman is a member of several of the Committees of the AMERICAN WELDING SOCIETY.

National Electrical Manufacturers Association

Electric Welding Section

Realizing the need for cooperative development of the industrial applications on the electric welding process, the Electric Welding Section of the National Electrical Manufacturers Association has established Development Headquarters in the Frick Building, Pittsburgh, Pa.

The Welding Section has initiated a program of cooperative industry development, to investigate the electric welding market and determine the possibilities of extending it. In this program especial attention will be given to application engineering, including:

(1) The preparation of reliable information on cost savings through the use of electric welding.
(2) The preparation of material for the use of and cooperation with construction engineers, designers and architects.
(3) The direct promotion of electric welding by missionary work on important new or undeveloped applications.

It has been conservatively estimated that by securing the widest possible adoption of applications which have been definitely successful, the use of electric welding in the metal fabricating industries can be increased at least fourfold.

Mr. H. S. Card, formerly editor of "The Welding Engineer" and author of "The Welding Industry," has been appointed Development Director of the NEMA Electric Welding Section and will be in charge of the Pittsburgh office effective October 1st.

Report of President J. J. Crowe on Activities of American Welding Society for Past Eighteen Months, Commencing April 1935

As prescribed by the By-Laws, your President is here rendering a report on the activities of the Society during his administration. By recent amendment of the By-Laws, eliminating this year the Spring meeting heretofore held for the Election of Officers and transaction of other business, the term of office of your President has been extended six months, and this report covers the eighteen months that have elapsed since taking over the office in April 1935.

As there appears in the Society Yearbook an account of the activities of your various committees up to the time of the publication of the Yearbook in August 1936, it is deemed unnecessary to repeat this information. However, it is believed desirable in this report to touch on the principal events or accomplishments of the administration. Notably among these are the following:

Specifications for the Design, Construction, Alteration and Repair of Highway and Railway Bridges by Fusion Welding.—The definite need for a Specification of this nature was brought to light early in 1932. After a thorough search for the best available talent the activity was inaugurated by Dr. Jacobus in July 1934 with Mr. P. G. Lang, Jr., of the Baltimore & Ohio Railroad, as Chairman. The composition of the Committee comprised outstanding representatives of various welding interests, designers and builders of highway and railway bridges, prominent consulting engineers, research specialists and engineering representatives of the manufacturing interests. The number of other national engineering societies represented in this personnel is worthy of comment. It included such organizations as the American Association of State Highway Officials, American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering Association, and the American Institute of Steel Construction. The work of the Committee and its important subcommittees was pushed virgorously, and early in 1936 the Committee submitted the Specification for the approval of the Board of Directors with recommendation that it be promptly printed and circulated in order that it be put to the test of actual use. Since the publication of the Specification there has been indication of its adoption by the American Railway Engineering Association and the American Association of State Highway Officials. Much credit is due Chairman Lang and to the members of his Committee for this outstanding accomplishment. A new Committee has been organized for the review and interpretation of the Specification in order that proposals for the amplification of the specification and questions rising in connection with it, will be properly handled.

Rules for the Qualification of Welding Processes and Testing of Welding Operators.—The demand for such rules has become quite urgent, your Committee worked toward the elimination of confusion by correlating varying qualification tests requirements by merging them into one uniform code, adequate to satisfactorily qualify welding operators working under any and all codes, and using any of the established fusion welding processes. It is the purpose of these qualification tests (1) to adequately determine the quality of a fusion welded joint by the specific process used and this having been determined, (2) to test the ability of the welding operator to apply that process. The Committee's task was not an easy one. After two years of the most intensive study in which all existing welding codes and specifications have been analyzed with a view to determining not only the purpose, but also the method involved in qualifying the operators, the Committee submitted for the Society's approval, a document which it believes gives promise of stabilizing and rendering practical, this rather difficult element of qualifying both the process and the operator of fusion welding. These rules have been published as a supplement to the October 1936 JOURNAL. They are intended to be tentative rules offered for study and trial during the ensuing year. The Committee that prepared these rules should be commended for this splendid piece of work.

Filing Classification System on Welding and Its Allied Processes, Materials and Applications.—This system intended for a general filing system, was prepared by a subcommittee of the Nomenclature Committee and is based on actual experience over a two year period. It is intended to make the filing system available in mimeograph form and is obtainable from the Society office for a nominal fee.

Welding Research.—Most of you are familiar with the accomplishments of the Fundamental Research Committee and the Structural Steel Welding Committee of the Bureau of Welding Research whose reports have frequently been brought to your attention through the columns of the JOURNAL. About a year ago Engineering Foundation recognizing the need of a comprehensive coordinated program of research in the welding field appropriated five thousand dollars a year for initiating a movement for the work of a Welding Research Committee sponsored jointly by the AMERICAN WELDING SOCIETY and the American Institute of Electrical Engineers. The second appropriation of five thousand dollars for the year beginning October 1st was made with the distinct understanding that this appropriation would be supplemented by cash contributions from industry of a sufficient magnitude to enable the Committee to carry out its well considered plans for (1) making a critical digest of the world's welding literature in order to increase the effectiveness of research workers and to make generally available in usuable form recorded knowledge, (2) stimulating research work in universities, forty of which are already cooperating with the Fundamental Research Committee and (3) coordinating industrial research activities in so far as such coordination will not interfere with work of a temporarily confidential nature. The Committee plans to supplement the Foundation appropriation by raising twenty thousand dollars. Half of this amount has been pledged and the work is well under way. The Society's JOURNAL has been temporarily selected by the Committee as the official organ for the Committee's work.

National Electrical Manufacturers Association's Offer of Cooperation.—The plan proposed was to raise money through contributions from the manufacturers of welding equipment and supplies with the help of such organizations as the Welding Section of NEMA, the International Acetylene Association and the Resistance Welding Association. At the request of NEMA a program of activity was outlined and a budget covering the Society's needs was prepared by your finance Committee and after the Board of Directors at its meeting on February 4, 1936, approved in principle the program as outlined in this Budget, it was turned over to a Committee to determine Ways and Means of carrying it out. It is expected that the Committee will render report at the coming meeting of the Directors.

Welding Handbook.—Considerable progress was made during the early part of the year in the preparation of plans for the publication of the first Welding Handbook, the securing of pledges for underwriting expenses and in obtaining the consent of authors to prepare chapters. The Directors at their meeting on February 4, 1936 voted to postpone action on the publication of the Handbook, awaiting recommendations of your Committee on Ways and Means. It is hoped that the work will be pushed soon after your Committee on Ways and Means renders its report.

Sections.—During the past year and a half two new Sections have been organized—one in Maryland and the other in Milwaukee. Both of these Sections, as well as most of the other Sections of the Society have held some very interesting meetings and have been active in building up their membership. There appears to be a need for assistance in reviving interest in both the Portland and Western New York Sections.

New Appointments.—The following appointments have been made during the past year:

An Educational Committee whose purpose is to plan and promote activities of an educational nature in cooperation with the Sections and National Membership Committee. The Chairman of this Committee has outlined an excellent plan for a course on the fundamentals of welding which he hopes to advance during this Convention. The activities of this Committee will undoubtedly contribute much toward increased membership in the Society.

A Committee to Consider Ways and Means of Developing Inspection Methods Used in the Manufacture of U-69 and U-70 Pressure Vessels.—This Committee is to consider means of developing suitable data and a procedure for the interpretation of the inspection of the trepanned plugs, and means of developing a satisfactory procedure and method or methods for closing the opening caused by the removal of the plug. This Committee has already had one or two meetings.

A Committee on Standard Tests for Welds.—It is the purpose of this Com-

mittee to formulate details for Standard Tests for Welds which may be used by other code and specification bodies in preparing minimum requirements for the qualification of operators. This Committee hopes to be able shortly to offer tentative specifications.

Committee to Confer with the Bureau of Navigation and Steamboat Inspection on the Qualification of Welding Operators.—This Committee has rendered assistance to the Bureau on the matter of qualifying welding operators.

Representation of Other Technical Societies.—Includes that of F. T. Llewellyn on the National Research Council, Engineering Division; H. L. Maxwell on ASM Recommended Practice Committee, and J. W. Owens on ASA Sectional Committee on Graphical Symbols and Abbreviations.

By-Law Amendments.—During the past eighteen months a number of By-Law Amendments have become effective. In general, these cover (1) the elimination of the Spring meeting of the National Society and its effect upon the Election of Officers, (2) the change in membership classification to raise the standard of membership so as to make the Society professional in character and (3) Reorganization of the American Bureau of Welding.

Membership.—During the past year the dues for the Member grade were lowered from $20 to $15 and the requirements for membership for this grade made to correspond to that of a professional engineer. For the first time in many years the number of Sustaining Members was materially increased. Fourteen Sustaining Members were added, representing almost a 50% increase in this classification. The total membership on September 1, 1936 was 1817 (43 A, 368 B, 972 C, 380 D, 2 E and 52 F). 1337 of these were classed "Active," and 480 delinquent over 6 months. The dues of the active membership represent $17,240. The committee has been very active under the direction of Mr. A. F. Davis, the new Chairman.

Finances.—At the end of the Society's fiscal year (March 31, 1936) the gross income showed an increase of 1.2% over the preceding year, which gain was distributed as follows:

Membership Dues	Increase	$ 62.19	0.5%
Journal Advertising	Decrease	511.80	7.1%
Subscriptions	Increase	64.34	2.5%
Printed Matter and Sundries	Decrease	35.13	3.7%
Fall Meeting Exposition	Increase	686.44	111.3%
Net Gain.....		$266.04	1.2%

Expense showed an aggregate increase of $383.58 sub-divided as follows:

Journal Expenses	Increase	$642.15	7.6%
Salaries, Rent and A. B. of W.	Increase	161.39	1.5%
Fall Meeting, Annual Dinner Membership and Promotion	Savings	963.41	50.6%
Miscellaneous Administrative	Increase	543.45	3.0%
Net Increase.....		$383.58	1.7%

Our net profit for the year ending March 31, 1936 was $51.63 as compared with a profit of $169.17 the previous year showing a decrease of $117.54, largely due to the falling off of advertising.

Comparative figures showing net operating result of the first five months of this fiscal year (April to and including August 1936) compared with that of the same period in 1935 are as follows:

	Gross Income	Gross Expense	Net Operating Result
1936	$9536.64	$9812.02	Loss $275.48
1935	$7937.33	$8859.11	Loss $921.78

During the first five months of this fiscal year (April to and including August 1936) the net operating result shows a loss of $275.48 against a loss of $921.78 for the same period in 1935. Because of the publication of the Yearbook in August of this year the expenses for that month were increased by $595.63 over that of August 1935 when the Yearbook was not published. Were it not for this additional expense, a profit would have been shown.

Members of the Executive Committee and Board of Directors are furnished with monthly financial statements and curve sheets every quarter showing fluctuations in net operating result and net working capital of the Society for the current year compared with the past few years. It is encouraging to note that even though the greater part of the membership dues (representing the Society's chief income) are collectable around the beginning of the *calendar* year, the first five months of this *fiscal* year, April to and including August, showed a marked improvement, consideration of course, being given to additional expenses incurred for promotional and general activities. This improvement is due to the activities of the Membership Committee, profit on sale of Bridge Specifications and other bulletins, and to the fact that the business of the Society is conducted on a most economical basis.

October 1936.

SECTION ACTIVITIES

BOSTON

At the Executive Committee meeting held on October 16th, J. F. Jenks and E. D. Debes were elected as Directors of the Boston Section to fill the unexpired term of C. W. Babcock and J. H. Zimmerman, who have resigned their positions as Directors. The term expires in April 1937.

Mr. H. R. Bullock, member of the Fundamental Research Committee, and member of the Boston Section, gave a very interesting talk on "High Speed Studies of Cutting" at the first regular meeting of the season. Slides and motion pictures were used to excellent advantage during his talk. The meeting was held at the Massachusetts Institute of Technology on October 16th.

CHICAGO

At the meeting on October 16th held at the Armour Institute, Mr. F. C. Fantz, Vice-President, Midwest Piping and Supply Company discussed qualification of welders with particular reference to the high-pressure piping code, and Mr. Frank H. Carpenter, Superintendent, Federal Pipe & Supply Co., discussed material specifications and testing of welded pipe assemblies.

The following is the program of the forthcoming meetings of the Chicago Section:

Friday, November 20th—Subject: "Welding—The Solution of Many Industrial Problems."

Monday, December 14th—Subject: "The Influence of Welding on Maintenance of Way Practices."

Auditorium Hotel.

This is a joint meeting with the Maintenance of Way Club of Chicago.

Friday, January 15, 1937—Subject: "Welding Non-Ferrous Metals."

Friday, February 19, 1937—Subject: "The Relationship Between Weld Metal and Base Metal."

Friday, March 19, 1937—Subject: "The Assembly of Heavy Sections by Welding."

Meeting place to be announced later.

Friday, April 16, 1937—Subject: "Welding in Modern Building Construction."

Friday, May 21, 1937—Subject: "New Developments in Welding."

The meeting on November 20th will start at 7:15 with a motion picture reel on "Services Performed by the U. S. Coast Guard," which picture will be in charge of Mr. M. K. Hudson of the Coast Guard.

The meeting itself, which will begin at 7:45 will be devoted to maintenance work of a seasonal nature, dealing particularly with boilers, cylinder heads, motor blocks, etc. One of the speakers will be Mr. Fred Lasker of the Lasker Boiler & Engineering Corporation of Chicago, who will describe methods of boiler repair. The other speakers have not yet been decided upon. The chairman of the meeting will be Mr. L. C. Monroe of *The Welding Engineer*. A dinner at 6:30 will precede the meeting.

CLEVELAND

Mr. Leon C. Bibber, Welding Engineer of the Carnegie-Illinois Steel Corporation was the speaker at a recent meeting of the Cleveland Section held on Nov. 11th. His subject was "Some Factors of the Properties of Weld Metal," which was illustrated with lantern slides. Mr. A. B. Einig, General Manager of The Motch & Merryweather Machinery Company gave a short talk on "Industrial Conditions in Russia."

DETROIT

Prof. Elihu Thomson, one of America's greatest pioneers in the field of electrical science and holders of more than 800 patents, was honored Friday night, Oct. 16th when the Detroit Section of the AMERICAN WELDING SOCIETY dedicated its program to the fiftieth anniversary of one of Prof. Thomson's greatest inventions, that of resistance welding. The meeting was attended by approximately

300. Mr. Albert E. Hackett of Thomson-Gibb Electric Welding Company presented a program commemorating the Fiftieth Anniversary of Resistance Welding and honoring its inventor, Professor Elihu Thomson.

Honored guests at this meeting were Malcom Thomson, who represented his father Professor Thomson; Mr. Lemp, Consulting Engineer for Ingersoll-Rand Company and an early associate of Professor Thomson; Mr. Francis Juhl of Greenfield Village another early associate of Professor Thomson. Chairman of the meeting was Colonel A. S. Douglass of the Detroit Edison Company who was introduced by Mr. C. L. Eksergian of the Budd Wheel Company.

Through arrangements made by Albert E. Hackett, Chairman of the Detroit Section, the original welding transformer perfected by Prof. Thomson, now the property of the Franklin Institute in Philadelphia, was brought to Detroit. A. L. Rohrer, former electrical superintendent of the General Electric Company, who helped Prof. Thomson with the original experiments fifty years ago, spoke from the exact spot where the welding development work took place on the second floor of an old G-E factory building in Lynn, and his voice was carried by wire and reproduced at the meeting by a public address system.

Prof. Thomson's health is such that he was unable to make the trip from his home but he sent a special message which his son, Malcolm, read to the Society. Prof. Thomson, now in his 84th year, is one of the co-founders of the General Electric Company. He is the holder of numerous medals and awards and is the only scientist in the world who possesses the three most coveted awards of English scientific and engineering institutions, the Faraday, Kelvin and Hughes medals.

LOS ANGELES

The regular meeting was held on October 22nd at the Los Angeles Chamber of Commerce Building with fifty members and guests present.

The speaker, Mr. J. D. Cunningham, Radiographic Engineer, Western Pipe and Steel Co., gave a very interesting talk on "X-Ray Inspection of Welds." The history, development and technique of radiography was presented in a concisive and interesting manner. Xographs illustrating various faults in heavy plate welds were shown on a view box.

Mr. P. D. McElfish, program chairman, received the approval of the group to hold no meeting until December 3rd, at which time the speaker will be Mr. W. C. Maine of Youngstown Sheet and Tube Co. His subject will be "Welded Oil Well Casing."

MILWAUKEE

The following officers were elected for the Milwaukee Section:

Chairman—L. J. Larson, A. O. Smith Corp.

Vice-Chairman—Klaus Hansen, Harnischfeger Corp.

Secretary-Treasurer—J. J. Chyle, A. O. Smith Corp.

The following directors were elected for two years:

Armin Kaiser, Linde Air Products Company.

Herbert Quartz, Allis Chalmers Mfg. Co.

Emil Behling, Vilter Mfg. Company.

The following directors are fulfilling their second year:

W. E. Crawford, A. O. Smith Corp.

Richard Sternke, Lakeside Bridge & Iron.

Gustave Johnson, Air Reduction Sales Corp.

The first meeting of the 1936–37 season held on Thursday, November 5th at the Milwaukee School of Engineering at 8:00 P.M. Monthly meetings will be held thereafter on the second Wednesday of each month.

The Milwaukee Section expect to have a very active and interesting season this year and hope to double their membership.

NEW YORK

The regular monthly meeting of the New York Section will be held on Tuesday, November 17th in the Engineering Societies Building. Messrs. E. S. Davenport and R. H. Aborn, of the Research Laboratory, U. S. Steel Corporation, will speak on the subject "Metallurgical Aspects of Welding Steel," which will be followed by discussion.

PHILADELPHIA

The Philadelphia Section had the pleasure of hearing a talk by Dr. C. A. Adams at its meeting on October 26th. Dr. Adams spoke on "Research and the American Welding Society."

The speaker at the November meeting is to be Mr. R. K. Hopkins of the M. W. Kellogg Company, whose paper will be entitled "Welding of Chemical and Refining Equipment."

PITTSBURGH

The opening meeting of the 1936–37 Fall Season was held Wednesday night, Oct. 21st, in the Roosevelt Hotel and was well attended notwithstanding the numerous counter attractions being held both in this city and in Cleveland where the National Convention was in session.

Deviating from the usual practice of having one or two prominent speakers address the Section the meeting was thrown open for the Members to bring in their troublesome problems for solution. It goes without saying that some were not answered. However, it was the consensus of opinion that it was a well worth while meeting, and several asked that other meetings of the same kind be held in the future.

Before throwing the meeting open for the discussion of problems the Members were treated to a very interesting motion picture film of the "Welding Arc," a General Electric Company research department film showing the arc in action in making various types of fusion welds.

SAN FRANCISCO

The October meeting of the San Francisco Section was held on the 30th at the Athens Athletic Club in Oakland. The Secretary reviewed the various codes and specifications available for purchase by members or friends of the Society. Mr. Davenport, Chairman of the Membership Committee, reported on the activities of his Committee. Chairman Mathy introduced Mr. E. Brooker, Engineer of the Standard Oil Company, who reviewed the last issue of the AMERICAN WELDING SOCIETY JOURNAL, commenting on various outstanding articles. The speaker of the evening was then introduced as Dr. Von Plank of the Columbia Steel Company who spoke on the extremely interesting subject "Low Alloy High Tensile Steel."

(*Continued from page 22*)

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